MYCOLOGIA

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Vol. LIII NOVEMBER-DECEMBER, 1961 No. 6

CONTENTS

William Alphonso Murrill.....GEORGE F. WEBER 543

Physiological studies on Calvatia species. II. Carbon utilization...M. SEDLMAYR, E. S. BENEKE, AND J. A. STEVENS 558

A laboratory procedure for the cultivation and fructification of species of Hericium
JOHN A. YURCHENCO AND GEORGE H. WARREN 566

The genus Schizophyllum.....WM. BRIDGE COOKE 575

A new species of Elsinoë on Panicum virgatum
LOIS H. TIFFANY AND JUDITH H. MATHRE 600

A study of Russula types, II.....L. R. HESLER 605

Reviews..... 626

Index..... 632

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TABLE OF CONTENTS

No. 1. January–February

Mycology and medicine, Chester W. Emmons 1
Fungi from salt lakes. I. A new species of Clavariopsis, C. J. Anastasiou 11
North American species of Puccinia on Hyptis, John W. Baxter 17
The genus Schenella, G. W. Martin 25
Some fungal parasites of Liliaceae, D. B. O. Savile 31
Infection with Histoplasma duboisii in different experimental animals, Masahiko Okudaira and Jan Schwarz 53
A new Emericellopsis from Wisconsin, with notes on other species, M. P. Backus and P. A. Orpurt 64
Studies in fungal luminescence, Martha D. Berliner 84
The effect of temperature on ascogonial and perithecial development in Ceratocystis fagacearum, F. W. Cobb, Jr., C. L. Fergus, and W. J. Stambaugh 91
Physiological studies on Calvatia species. I. Vitamin requirements, M. Sedlmayr, E. S. Beneke, and J. A. Stevens 98
Financial Reports 109

No. 2. March–April

Julian Howell Miller (1890–1961), W. A. Campbell 111
Studies on the intracellular amino acids of Penicillium roqueforti, E. Meyers and S. G. Knight 115
Studies on Calvatia gigantea. I. Germination of the basidiospores, Glenn S. Bulmer and Everett S. Beneke 123
A preliminary report of the Myxomycetes of southern Arizona, Adelaide E. Evenson 137
Stereum taxodii in Japan and Formosa, Kiyowo Aoshima, Paul L. Lentz, and Hazel H. McKay 145
A bluestain in balsam fir, René Pomerlau and D. E. Etheridge 155
Structure, germination, and physiology of microsclerotia of Verticillium albo-atrum, R. S. Gordee and C. L. Porter 171
Parasitism of Olpidiopsis incrassata on members of the Saprolegniaceae. I. Host range and effects of light, temperature, and stage of host on infectivity, Miriam K. Slifkin 183
Fine structure of Mycota. 5. Lomasomes—previously uncharacterized hyphal structures, Royall T. Moore and James H. McAlear 194
The genus Phaeodaedalea, M. E. P. Kauffmann Fidalgo 201
Reviews 211

No. 3. MAY–JUNE

New species and revisions in the order Tuberales, HELEN MARGARET GILKEY 215
A re-evaluation of Arachniotus indicus, GOURI RANI GHOSH, G. F. ORR, AND H. H. KUEHN 221
Notes on boletes. XIV, WALTER H. SNELL AND ESTHER A. DICK 228
A simple technique for investigating stromatal formation in the Sclerotinaceae, CARMINE NOVIELLO AND RICHARD P. KORF 237
Heterocaryosis and somatic recombination in Cephalosporium mycophilum, R. W. TUVESON AND D. O. COY 244
A species of Endogone from corn causing vesicular-arbuscular mycorrhiza, J. W. GERDEMANN 254
Botryodiplodia theobromae and its association with Musa species, ROGER D. GOOS, ELSIE A. COX, AND G. STOTZKY 262
Two species of Conidiobolus often forming zygospores adjacent to antheridium-like distentions, CHARLES DRECHSLER 278
Basidiospores of several species of Agaricales discharged and collected in pairs, E. B. LAMBERT AND T. T. AYERS 304
Entomophthora coronata, the etiologic agent of a phycomycosis of horses, CHESTER W. EMMONS AND CHARLES H. BRIDGES 307
Reviews 313

No. 4. JULY–AUGUST

Studies of some Tremellaceae. IV. Exidiopsis, KENNETH WELLS 317
Cercospora species on cucurbitaceous hosts in South India. I. Identification of species, G. RANGASWAMI AND S. CHANDRASEKARAN 371
Some viewpoints on the phylogeny of rust fungi. IV. Stem rust genealogy, E. E. LEPPIK 378
Notes on Mucorales, especially Absidia, C. W. HESSELTINE AND J. J. ELLIS 406
Notes on western rust fungi I. Chrysomyxa, ROGER S. PETERSON 427
Notes and Brief Articles 432

No. 5. SEPTEMBER–OCTOBER

A taxonomic analysis of section Athele of the genus Corticium. II, ANTHONY E. LIBERTA 443
New or noteworthy Penicillia from Wisconsin soils, MARTHA CHRISTENSEN AND M. P. BACKUS 451
A new species of Choanephora from India, B. S. MEHROTRA AND M. D. MEHROTRA 464
A new species of Didymosphaeria from the rhizosphere, T. K. RAMACHANDRA-REDDY 471
Synopsis of the Polyporaceae of the western United States and Canada, JOSIAH L. LOWE AND ROBERT L. GILBERTSON 474
Morphological studies in the Chaetomiaceae. I, W. C. WHITESIDE 512
The distribution of Emmonsia crescens in Europe, WILLIAM L. JELLISON AND J. WILLIAM VINSON 524
Notes and Brief Articles 536

No. 6. NOVEMBER–DECEMBER

William Alphonso Murrill, GEORGE F. WEBER 543
Physiological studies on Calvatia species. II. Carbon utilization, M. SEDLMAYR, E. S. BENEKE, AND J. A. STEVENS 558
A laboratory procedure for the cultivation and fructification of species of Hericium, JOHN A. YURCHENCO AND GEORGE H. WARREN 566
The genus Schizophyllum, WM. BRIDGE COOKE 575
A new species of Elsinoë on Panicum virgatum, LOIS H. TIFFANY AND JUDITH H. MATHRE 600
A study of Russula types, II, L. R. HESLER 605
Reviews 626
Index 632

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WILLIAM ALPHONSO MURRILL

GEORGE F. WEBER

William Alphonso Murrill died, after a month's hospitalization, on 25 December 1957, in his 88th year, in Gainesville, Florida, where he spent the last quarter century of his distinguished career in an active retirement. To the very day of his final illness, he pursued a leisurely existence, enjoyed plants, people as he found them, and his own popularity. As a hobby he collected and described mushrooms of Florida.

Dr. Murrill was born 13 October 1869 at Pammell Farm near Lynchburg, Virginia, and grew up with three brothers and three sisters. His ancestors of Scotch-Irish-Welsh lineage were thrifty, talented, ambitious, religious citizens. Basic principles of fair play, obedience, and aesthetic appreciation were obtained in his youth directly from his father, Samuel L. Murrill, and his mother, Virginia Woodroof Murrill. He might have become a doctor, lawyer, preacher, or politician as easily as a naturalist. Early schooling was varied, from the three R's to church activities, appreciation of music, and expeditions into the surrounding marginal woodlands and forests. He entered Virginia Agricultural and Mechanical College at Blacksburg when he was twelve years of age, and was graduated in 1887 with highest honors, receiving the degree of Bachelor of Science. An additional degree of Bachelor of Science was received from Randolph Macon College in 1889, the degree of Bachelor of Arts in 1890, and the degree of Master of Arts in 1891. During these academic years he always helped his father on the farm in the summer, closely observing nature, and studied Latin, Greek, music, and philosophy.

He taught the natural sciences at Bowling Green Seminary for two

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years and at the Wesleyan Female Institute for four years (both schools located in Virginia). During the few years at Staunton he made frequent visits to the University of Virginia at Charlottesville where selected lectures were attended and professors in many departments were consulted. The zoology museum, the medical school, the chemistry laboratories, and the observatory were highly influential in generating the decision that he would be a naturalist. He was greatly impressed by the life of Agassiz. Murrill believed that the true scientist is the noblest of the race, without greed or hatred, an altruist and a lover of beauty, justice, and truth.

With these idealistic abstractions guiding youthful ambitions, William entered Cornell University in the fall of 1897, where he had been awarded a fellowship in botany. Here the contact with Professor George F. Atkinson was most fortunate. The professor, a tactical investigator and a teacher with forceful, driving energy, lent his interest and encouragement to his new student who accepted with pleasure the rough road laid out for him. He came in contact with Drs. J. H. Comstock, L. H. Bailey, E. J. Durand, K. M. Wiegand, and other scientists. He was a graduate assistant in botany during his second year. In his third year he succeeded B. M. Duggar as assistant cryptogamic botanist. He received his Doctor of Philosophy degree at Cornell University in 1900 with a dissertation on "Fertilization in the Hemlock Spruce." In the same year he was elected to Sigma Xi.

On 1 September 1897, he married Edna Lee Lutrell. Their only child, a son born in 1899, died in infancy.

His first job after graduate school was teaching biology at DeWitt Clinton High School in New York City for a four-year period. These four years did much toward maturing the young, energetic, all-absorbing Murrill. He joined the Torrey Botanical Club and met many local botanists. He was exceedingly interested in his teaching responsibilities, the acquiring of a broadened knowledge, and the gathering of plants and fungi for class illustrations. He rapidly became acquainted with the art galleries, churches, museums, and the other wonders of New York City.

At the end of his first year of teaching he spent his vacation in Europe where he attended the Botanical Congress at Geneva and the Zoological Congress in Berlin. He visited many interesting places, studied fungi and other plants, and returned with an extensive collection of foreign material. Another trip was made the next year during which time he gave lectures, supplemented his previous collections, and met some of the leading botanists and mycologists, amassing voluminous quantities of notes and biological specimens.

Dr. Murrill's home was close to Columbia University, and there he became an admirer of Dr. L. M. Underwood who appreciated the interest and enthusiasm of the young professor and aided him with facilities and opportunities for study of the fleshy fungi in the University's collection. The time spent there in study and contacts matured Murrill, extended his circle of acquaintances and strengthened his already abundant knowledge of the fungi. He said that he was advised to be liberal and charitable, to indulge in social activities with good people, and to avoid assuming the pose of a critic or puritan.

In 1904 he was appointed assistant curator at The New York Botanical Garden and then, in 1908, he was designated as assistant director for the Garden, in which capacity he continued until 1919. He was Supervisor of Public Instruction from 1919 until his resignation in 1924. He spoke in public with ease, wrote a good letter, met people graciously, made friends easily, and was of impressive stature, honest, kindly disposed, industrious, and dependable.

It was during the 20 years before his dissociation with the Garden that Dr. Murrill applied himself to his chosen profession of mycology. So effective were his efforts that he became eminently known as the foremost American student of the Hymenomycetes as represented by the Agaricales. His published contributions were many and are largely contained in the Journal of The New York Botanical Garden, Journal of the Elisha Mitchell Scientific Society, Bulletin of the Torrey Botanical Club, Lloydia, and Mycologia. Mycologia was founded by him as an avenue of publication for mycological information, scientific findings, and discussions. It was edited by him for the next sixteen years and its inaugural success was largely due to his efforts and contributions.

Murrill studied the forms and variations of the sporophores of Hymenomycetes from the entire United States, southward to Argentina, and in Europe. His annual collecting trips rewarded him bountifully with more than 70,000 specimens which are deposited in the Garden's herbarium. He took duplicates of his American species with him on most occasions for comparison and exchange to the numerous museums in foreign countries. The experiences and consultations with G. Bresadola, C. L. Spegazzini, J. P. Lotsy, M. C. Cooke, G. E. Massee, L. G. Romell, G. Lindau, P. W. Magnus, N. T. Patouillard, P. A. Hariot, and A. D. Cotton, and the comparison of their specimens with his, aided him in becoming one of the world's most experienced field observers of Hymenomycetes. The detailed reports of these annual expeditions are contained in the various volumes of the Journal of The New York Botanical Garden, usually of the same year.

At the Garden Dr. Murrill found ". . . a prevailing tradition of classification into a few unrelated and arbitrary genera and left a system of natural, well-defined and scientifically defensible ones. He found a nomenclature based on a variable and contradictory tradition and introduced one determined by exact history, clearly stated law, and logic. But . . . the precise nomenclature was that of the American Code, which was obligatory at the Garden . . . because it brought about many nomenclatural changes, was detested by those from whom anything once learned immediately became universal usage. The excellence of the Murrill classification was nearly lost in the accumulation of denunciation showered on the Murrill nomenclature, and only in recent years has mycology caught up with and, to a considerable degree, adopted the Murrill polypore taxonomy." (D. P. Rogers, Gard. N. Y. Bot. Gard. **8**: 75. 1958.)

Dr. Murrill first heard of the American Code when he was English language secretary for the International Botanical Congress held at Geneva, Switzerland, and later he became a member of the committee that framed the American Code, which he says probably would have been generally adopted at Vienna had it not been for "Engler's eighty somewhat questionable proxies used in the final vote." He thought this Code was too fair and strict for those wishing to conserve "pet names" so it was superseded by the International Code.

He was well prepared to compile and describe the species of Hymenomycetes for the North American Flora. In addition to curating the fungi, he had time-consuming administrative duties and at unexpected occasions was responsible for public instruction, departmental exhibits, plant disease control, and the entertainment of visitors from home and abroad.

The Holland Society of New York presented him with a gold medal in the spring of 1923 for his work in mycology.

Chestnut blight, later found to have been introduced from Japan, appeared in the Zoological Garden adjacent to The Botanical Garden in New York City, and in 1905 the disease was brought to the attention of Dr. Murrill. He made isolations of the fungus and inoculations of healthy trees, reproduced the typical disease, described the fungus and discussed the probable difficulty of effective control as a contribution to plant pathology.

The Murrills occupied a large, beautiful, well-furnished home near the Garden, filled with many art treasures and rare collector's objects from abroad. Mrs. Murrill served delicious dinners to their friends and to her husband's scientific friends. There was continuous entertainment

of a widely diversified guest list, but he most enjoyed children and groups of young people, particularly the Girl Scouts, with whom he spent most of his off duty hours, although he participated in rowing, swimming, tennis, volley ball, horseshoes, skating, bowling and camping.

"You can travel the museums of the world over and you will not meet a pleasanter, more affable gentleman than W. A. Murrill, assistant director of the New York Botanical Garden, in charge of the mycological department. Together we have enjoyed several visits, and I am much pleased to be able to publish his photograph in our series of prominent mycologists." (C. G. Lloyd, Mycol. Writings **4**: 290. 1915.)

His busy existence became clouded by a series of circumstances that culminated in the tendering of his resignation to the Director-in-Chief of the Garden in August, 1924, ending his public career that possessed every indication of abundant accomplishments. As he has said, the administrative responsibilities attached to his position, which were more or less of a burden to him, occupied so much of his time that there was none left to pursue his study of the fungi. In being an administrator he had to think for others as well as for himself. He reminisced that, "Tempted by a little prominence and a few extra dollars, my birthright was handed over and there was traded the immortality of the original investigator for the temporary and hollow smugness of an ordinary executive." He was hospitalized intermittently for over a year for correcting a nervous instability and physical exhaustion. His wife, with a feeling of neglect and with physical ailments resulting in inefficiency and moodiness, left his home and shortly thereafter served him with a divorce decree. Financial problems developed with which he was unable to cope; and as these events presented themselves, he became a man haunted, troubled mentally, alone, and discouraged. He left the Garden in an endeavor to escape the events that bore down on him, never to return, although several attempts were made to convince him that his responsibility to his science was most important.

"Word has just reached us . . . that, owing to failing health, Dr. Murrill will probably retire from the work. No one can be more genuinely sorry to learn this than ourselves. From the persistent way in which we have combated him, there probably is an impression that we have some personal feeling against him. That is not the case. It is the system of name changing which Dr. Murrill represented that we are unalterably opposed. But for Dr. Murrill personally we have always had the highest regards and the most pleasant relations and our favorite expressions in private conversation is that Dr. Murrill is the finest gentleman that ever engaged in the mycological game. We do not blame

him personally for what he did and had we been in his shoes we would have done exactly the same thing had we been smart enough." (C. G. Lloyd, Mycol. Writings 7 : 1332. 1924.)

Dr. Murrill changed from one plagued with the worry and responsibilities of a complicated society in high places to one devoting all his thoughts to his own individual self. He returned immediately to the woods, flowers, birds and animals in the neighborhood of his birth near Lynchburg, Virginia, where he stayed with an aunt, and in the course of the succeeding months mildly regained composure, peace of mind, health and self respect. He built a cottage in the woods where, when a boy looking for adventure and learning about nature, he had spent many leisure hours. He rejoiced in these familiar scenes, in his freedom, his carefree time, the lack of heavy responsibility, and the friendly, sympathetic people, and gradually overcame the apparent handicap of his misfortunes. He later commented to the effect that it is quite surprising how much space there is in a little house if the furniture is simple and conveniently arranged, and for once in his life he had a bed that suited him and there was plenty of room for his books. Men may be measured by the way they accept disappointment. An earlier meeting with Burroughs, whom he regarded highly, was probably most influential in aiding Murrill in his decisions in these hours of loneliness and change, and he imitated him in many ways.

He made a professional exploring and collecting trip to Florida in 1923, and after a year in Virginia the winter season found him again in the state, traveling leisurely from place to place. The visits to Gainesville became more and more frequent and of longer duration and, accidentally, it was on one of these visits that the writer first was impressed by the tall, dignified appearing, pleasant stranger living in the local tourist camp, who was entertaining the transient tourists at their recreation hall in the court by a piano concert of classical music.

Dr. Murrill decided to make Gainesville his home, and built his house and lived in it during the winter seasons, returning to Virginia during the summer time. His interest extended to a wide range of activities, including writing articles on natural subjects for publication in newspapers and magazines. The mosquito control problem in the city occupied some of his time, and because of it he remained in Gainesville over the summer months for the first time. The richness of the endemic biota and the vast opportunity to study the varieties and abundance of the fleshy fungi caused him to stay in Gainesville throughout the entire year thereafter. This resulted in his return almost exclusively to a critical study of these forms. Many hundreds of new species were discovered

and described. His enthusiasm was contagious. His many friends were solicitous of his happiness and were anxious to take him on collecting trips or bring their novelties to him for identification and an explanation. He was actively interested in the local garden clubs and organized a nature club that made weekly forays. The Girl Scouts work was pleasant. Church activities and Sunday School received much of his attentions, particularly in relation to his vast information of natural things, travels, experiences, and musical talent. He was kindly, patient, sincere, understanding, and worshipful to children and adults in his new environment. He lived alone and kept his own council regarding his past activities. He had no pension or retirement, and seemed to have no visible plan for the future. During the last fifteen years of his life he had no income except a few dollars derived from his dozens of science publications, written in popular language for the teenager. His physical needs were looked after by his Gainesville friends, and during the last few years he received some financial and medical support from the Florida Social Welfare Board. During the several years he consulted with many mycologists and visiting professors, including R. Singer, Gertrude Burlingham, L. R. Hesler, J. L. Lowe, D. Reddick, J. M. McFarland, H. C. Beardslee, and others.

He visited the University of Florida every day, curating his fungous acquisitions, and distributing many sets of his type materials to mycologists and institutional herbaria. He became a familiar and admired figure as he made almost daily trips to his favorite collecting grounds nearby. He was present during several sessions of the Mycological Society meeting with the A.I.B.S. in 1954 in Gainesville, conversing with those present and aiding in the determination of the extensive collections made on the foray.

During the last few years his applications became less and less regular, although his enthusiasm never diminished even up to the time of his last illness. Even then he reported of his own volition to the University Infirmary where he collapsed while the doctor was examining him. He did not want to die because there was too much interesting work yet to be done, yet he knew very well that the time had come. He said on his last birthday a few months past that he expected to live to be a hundred. He was the last surviving member of the early American Mycological Society. So ended the life so richly endowed with information, humility, sincerity, joyfulness, and kindliness.

His first joy and pleasure in his retirement was the study of the fleshy fungi of Florida, wherein he described over 600 new forms of agarics and over 50 polypores and hydnums. Dr. Murrill was an ardent photog-

rapher and artist; he was a capable writer, critic, and editor; he was a collector not only of fungi but of items of art, sculpture, paintings, stamps, and shells; he was a Sunday school teacher, a showman of the first order as a traveler, lecturer, scientist and philosopher. His composition of musical lyrics numbered in the hundreds of sheets; he was a friend of children, secretaries, nurses, his neighbors, the day laborers, and professional people.

"His was a very fruitful, full and successful life and his contributions to the science of botany are imperishable. It will be a long time before anyone will be able to fill his shoes." (Moldenke)

"I recall Dr. Murrill as a tall, immaculately dressed southern gentleman. I can yet see him as he strode the halls of the Botanical Garden with deliberation, dignity and poise." (Seaver)

"Being neither follower nor faddist, the results of his efforts in finding out if he could separate a large mass of valuable fungous specimens he and others had collected for the herbarium was not a chronique d'ordinaire. Although his works failed to enlist the help that the field offers in interpreting variations that may be attributed to the environment, he did create a meritorious framework of ideas for others to use—which they will—and for others to refine—which they will." (Baxter)

"As a pioneer he described many new species which were based mainly on macroscopic characters, placing greatest emphasis on the field characters, but when microscopic studies of his types are made it is often found that his species can be distinguished readily by these characters also. Hence his name will always be an important one in American mycology. He was the last of the old school of mycologists who placed greatest emphasis on the field characters for the fleshy fungi." (Smith)

"I have always regarded Dr. Murrill as a dynamic mycologist belonging to the morphology-taxonomy group. In classifying mycologists he would be considered a 'splitter' rather than a 'lumper'; hence there are those who would discard many of his species and would call them varieties. I wouldn't brand him as a maverick for his stand as an individualist as contrasted to a conformist, but rather admire him. One can't make a thing right by legislation as many mycologists believe. We need such men but not all mycologists should be like him, he has served well his profession." (Wolf)

"My time spent at the Garden was so profitable and enjoyable because Dr. Murrill was there. I learned his methods of study and the significance of carefulness, accuracy and industry in scientific work. He was a loyal friend, a sympathetic counselor, and cooperative associate. I have known few equal and none superior to him." (Kern)

"After some early disputes with him in which I criticised him a little too freely and for which I was sorry and apologized and which apologies were graciously accepted, we became friendly and he was very generous to me in several ways upon many occasions. Murrill was a sedulous collector and I have been told that he was an unusually perceptive field man. He was unfortunate as being the first serious revisionist in this country and he suffered for this precocity. Botanists were irritated by the changed names and new systems and he was roundly criticised, if not reviled, for his temerity. He, too early for his own good, saw the ultimate necessity of revision in the Hymenomycetes, but he was too early to gain acceptibility of fundamental change in systems of fungi and unlucky in not hitting upon systems which were fundamental and approaching natural relationships. He made many weird determinations and relationships, although some were good. No one did any better for a few decades." (Snell)

"In studying the cultural characteristics of a large number of the Polyporaceae a number of groups coincide quite closely with some of Dr. Murrill's genera. I think that he must have had a keen appreciation of relationship among species and the characters that express these relationships, and that the generic concepts he established are often very sound. Further correlation of cultures and sporophores must be made before this study can be properly evaluated." (Nobles)

"I have always felt a deep sense of gratitude to Dr. Murrill for his patience and kindness toward an ignorant beginner in this field. During his active years he gained the reputation as a 'splitter' by those who had no sympathy with his views. As I've told my students, his views on the classification of the polypores were a generation or more ahead of those of most of his contemporaries and most of the current work in the United States has not yet caught up with him. I think there was more right on his side than on that of those who opposed him. It is my belief that current work will tend to vindicate his position on the generic question. He was a scholarly gentleman and a far better mycologist than most of his opponents are willing to admit." (Martin)

"Dr. Murrill, with a wealth of field and herbarium experience, was a tremendous compiler. His discriminating eye led to his recognition of a large number of new species which have withstood critical restudy under current methods. Of the myriads of collections which he studied, a vast number were taken in the field by himself—an invaluable advantage in his specialty. His contribution to North American agaricology is monumental. In time, under modern techniques, as his Florida types are restudied the reliability of his efforts will be even more widely recog-

nized. He was a proud and distinguished figure, a great mycologist, a wondrous personality, and generous to the extreme." (Hesler)

The factual data were derived from an autobiography, his family, Who's Who in America vol. 26, Lloyd's Mycological Notes, and his coworkers: D. V. Baxter, L. R. Hesler, F. D. Kern, G. W. Martin, H. N. Moldenke, Mildred Nobles, D. P. Rogers, F. J. Seaver, A. H. Smith, W. H. Snell, and F. A. Wolf.

Photographs of Murrill have been published in Lloyd's Mycological Writings **4**: 290, 1915; Mycologia **22**: 49, 1930; Mycologia Index Vols. 1–24, *frontispiece*, 1934; and Mycologia **48**: 457, 1956.

His remains are interred in the Evergreen Cemetery, Gainesville, Florida.

PUBLICATIONS OF WILLIAM A. MURRILL [1]

A complete list of Dr. Murrill's publications, including mycological and botanical papers and notes, general notes, miscellaneous reports, reviews, biographies, unsigned editor's notes, popular articles on natural history, etc., totals at least 510. One hundred and sixty five of these were published in Mycologia (1909–1932) and are indexed in MYCOLOGIA VOLS. 1–24 INDEX, p. 19–23, 1934.

The following list includes botanical and mycological papers published in Mycologia since volume 24 and in other journals, or published independently by Murrill. Nonbotanical publications have been excluded.

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The generative divisions in gymnosperms. Torreya **1**: 131, 132. 1901.

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The Polyporaceae of North America. I. The genus *Ganoderma*. Bull. Torrey Club **29**: 299–608. 1902; II. The genus *Pyropolyporus*. **30**: 109–120; III. The genus *Fomes*. 225–232; IV. The genus *Elfvingia*. 296–301; V. The genera *Cryptoporus, Piptoporus, Scutiger* and *Porodiscus*. 423–434. 1903; VI. The genus *Polyporus*. **31**: 29–44; VII. The genera *Hexagona, Grifola, Romellia, Coltricia* and *Coltriciella*. 325–348; VIII. *Hapalopilus, Pycnoporus* and new monotypic genera. 415–428; IX. *Inonotus, Sesia* and monotypic genera. 593–610. 1904; X. *Agaricus, Lenzites, Cerrena* and *Favolus*. **32**: 83–103; XI. A synopsis of the brown pileate species. 353–371; XII. A synopsis of the white and bright-colored pileate species. 469–493. 1905; XIII. The described species of *Bjerkandera, Trametes*, and *Coriolus*. 633–656. 1905 [1906].

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[1] Prepared by Clark T. Rogerson and Mary Fleming.

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A key to the perennial Polyporaceae of temperate North America. Torreya **4**: 165–167. 1904.
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Tomophagus for *Dendrophagus*. Torreya **5**: 197. 1905.
Collecting fungi in Maine. Jour. N. Y. Bot. Gard. **6**: 199–202. 1906.
A key to the Agariceae of temperate North America. Torreya **5**: 213, 214. 1906.
The pileate Polyporaceae of central Maine. Torreya **6**: 34–37. 1906.
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PHYSIOLOGICAL STUDIES ON CALVATIA SPECIES. II. CARBON UTILIZATION [1]

M. Sedlmayr, E. S. Beneke, and J. A. Stevens

The first physiological studies of *Calvatia* have proved to be an important field of further investigation. The optimum vitamin requirement of this organism has been already investigated, Seldmayr et al., **1961**. The present report deals with the carbon utilization of four strains of *Calvatia* species.

There are several reports in the literature concerning the utilization of carbon by different Basidiomycetes. Among them we cite Margolin (**1942**), Derrick (**1949**), Norkrans (**1950**), Norkrans and Ranby (**1956**), Bille-Hansen (**1953**), Oddoux (**1953**), Fries (**1955**), and Lamprecht (**1958**). However, Swartz (**1933**) was the only one who reported on the carbon requirement of *Calvatia* species. He found maltose the best sugar for producing mycelium of *Calvatia saccata, C. caelata* and *C. gigantea.*

EXPERIMENTAL PROCEDURE

Three strains of *Calvatia gigantea,* 1018 F, 1019 B, 766, and *Calvatia fragilis* 1020, were employed in these studies for the utilization of different carbon sources. The basal synthetic medium was Lindeberg's medium with 100γ/liter of thiamin added. The pH was determined at the time the mycelium was harvested.

Forty ml of the modified Lindeberg medium was placed in a 125 ml Erlenmeyer flask and plugged with nonabsorbent cotton. Only Pyrex glassware was used and it was washed as described in the first part of this study. Each flask was autoclaved for 15 minutes at 15 pounds steam pressure.

Various carbohydrates were added to the basal medium in quantities which supplied 8 grams of carbon per liter. In most of the experiments, the carbohydrates were added to the basal medium before autoclaving. Maltose, trehalose and raffinose were sterilized separately in the autoclave for shorter periods of time and at less pressure (according to their heat sensitivity) and added aseptically to the basal medium.

[1] Contribution number 61-9, Department of Botany and Plant Pathology, Michigan State University, East Lansing, Michigan.

To avoid the breakdown of sugars during autoclaving, the heat-sensitive carbohydrates, fructose, L-sorbose, xylose, melibiose and invert sugar, were sterilized by Seitz-filtration using a filter with 1 μ pore diameter.

The density of the inoculum was determined using a Klett-Summerson photoelectric colorimeter with a green filter (spectral range 500–570 mμ). For these experiments, inocula giving a 30–35% transmission reading were used. Each of the flasks was inoculated with 1.0 ml of the blended suspension.

The cultures were incubated on the previously described reciprocating shaker, with no additional aeration. All the experimental flasks were incubated at approximately 25° C. The cultures were exposed to diffuse daylight with intervening dark periods at night. No attempt was made to standardize the illumination.

Sufficient flasks were inoculated to provide two replicates for each strain harvested after 14 and 28 days on the shaker. The mycelium was filtered on tared Whatmann No. 1 filter papers using a Buchner funnel, and washed twice with distilled water. It was then dried to constant weight for 24 hours at 96° C in oven. The average dry weight of mycelium was then calculated.

DISCUSSION AND RESULTS

In this study, all of the carbon sources tested were present in an amount calculated to yield an equal supply of carbon. Therefore, it was possible to compare their utilization by the four *Calvatia* strains on an equitable basis.

Monosaccharides. The experimental evidence shown in TABLE I indicates that pentoses were utilized less well than most of the hexoses by *Calvatia* species. When any of the 5-carbon sugars were used as the sole carbon source, the strains used grew poorly. There are slight differences, however, in the utilization between the strains and also between the availability of the pentoses.

Ribose was the best carbon source among the pentoses for strains 1018 F, 1019 B and 1020 after 28 days on the shaker. Strain 766 did not grow in the presence of ribose in the basal medium. *Calvatia* species were not able to satisfy their carbon requirements with either xylose or arabinose. The growth of the strains was more rapid and greater dry weights of mycelium were produced in autoclaved than in sterile filtered xylose, even though less yield was expected with the autoclaved xylose because this pentose is known to be broken down to furfural in autoclaving.

TABLE I

THE UTILIZATION OF VARIOUS MONOSACCHARIDES BY CALVATIA SPECIES. REPORTED AS THE MYCELIAL DRY WEIGHTS OF TWO REPLICATES*

C-sources	1018 F				1019 B				766				1020			
	14 days		28 days		14 days		28 days		14 days		28 days		14 days		28 days	
	mg	pH	mg	pH	mg	pH	mg	pH	mg	pH	mg	pH	mg	pH	mg	pH
Pentoses																
L-arabinose	2.3	5.3	3.4	4.7	4.9	5.0	7.6	4.9	2.1	5.2	3.6	4.9	2.5	5.0	4.2	4.9
D-arabinose	2.7	5.1	4.9	4.9	2.0	5.0	3.5	4.9	0	5.5	2.7	5.1	2.3	5.0	4.8	4.9
d(+) xylose (autoclaved)	3.3	5.2	5.1	4.8	4.2	5.3	6.5	4.6	4.0	5.1	6.8	4.8	4.1	5.0	6.0	4.8
d(+) xylose (filtered)	1.7	5.5	3.7	5.3	2.2	5.3	3.7	5.2	2.0	5.2	3.5	5.1	1.6	5.4	5.3	5.2
d(−) ribose	3.3	5.5	7.0	5.2	4.3	5.2	9.5	5.0	0	5.5	0	5.4	2.8	5.3	7.5	5.0
rhamnose	0	5.5	1.9	5.3	0	5.5	3.1	5.2	0	5.5	2.7	5.4	0	5.5	2.4	5.3
Hexoses																
d(+) glucose	13.0	5.3	39.1	4.5	14.4	5.3	27.2	4.5	4.4	5.3	11.1	5.0	11.7	5.3	52.1	4.8
d(+) galactose	1.4	5.5	4.2	5.0	1.3	5.3	11.8	4.6	4.6	5.2	8.1	4.9	5.1	4.9	28.8	4.5
d(+) mannose	14.5	5.0	15.5	4.8	8.8	5.0	9.3	4.8	4.4	5.0	6.6	4.9	2.2	5.3	24.1	4.7
l(−) fructose	3.2	5.4	22.6	4.9	2.6	5.4	15.8	5.0	2.3	5.4	7.9	5.2	3.3	5.2	20.2	5.0
L-sorbose	1.4	5.4	4.6	5.0	0	5.5	2.5	5.2	0	5.5	2.0	5.3	1.8	5.3	3.5	5.1
Oligosaccharides																
sucrose	3.3	5.2	10.9	5.0	5.6	5.3	13.7	5.1	1.8	5.2	5.0	5.1	4.9	5.5	10.1	5.3
d(+) maltose	2.7	5.3	40.8	4.8	2.9	5.4	46.1	4.0	2.0	5.5	10.3	5.0	5.5	5.3	26.9	5.0
d(+) lactose	3.0	5.5	4.9	5.5	1.8	5.5	5.5	5.3	2.2	5.5	5.7	5.5	2.7	5.5	6.9	5.3
cellobiose	7.6	5.4	53.5	4.5	20.5	5.0	43.0	4.5	9.7	5.2	21.3	4.9	52.3	4.6	146.0	4.0
melibiose	1.8	5.5	3.8	5.3	1.5	5.5	3.0	5.5	0	5.5	2.0	5.3	2.1	5.4	5.1	5.3
trehalose	4.7	5.2	13.0	4.9	8.3	5.2	23.1	4.9	6.3	5.3	9.3	4.9	7.2	5.2	20.5	5.0
invert sugar	5.1	5.2	22.1	4.7	8.6	4.9	46.2	4.5	5.2	5.2	16.5	4.8	10.9	4.9	64.3	4.4
d(+) raffinose	7.2	5.3	9.5	5.1	6.2	5.3	8.3	5.0	2.6	5.4	5.9	5.1	5.6	5.2	7.9	5.0
Polysaccharides																
cellulose	0	5.3	2.8	5.1	2.1	5.3	3.3	5.2	0	5.3	3.2	5.1	1.9	5.3	4.2	5.1
dextrin	4.6	5.0	20.3	4.7	7.9	4.9	85.6	4.4	12.0	4.8	31.6	4.5	73.8	4.3	153.1	4.0
starch	6.8	5.1	9.8	5.0	8.3	5.0	23.2	4.9	7.8	5.0	13.2	5.0	9.2	5.0	33.1	4.5
inulin	4.8	5.1	6.9	5.0	3.9	5.5	8.7	5.4	2.1	5.5	2.9	5.2	7.7	5.4	9.9	5.2
glycogen	5.9	5.1	13.7	5.0	9.1	5.3	21.0	5.1	10.3	5.5	14.9	5.0	15.1	5.3	90.2	4.8
Control																
C-free medium	0	5.5	1.2	5.5	0	5.5	1.1	5.5	0	5.5	0	5.5	0	5.5	1.4	5.5

* The dry weights in mg for the two replicates listed were very nearly equal before averages were made.

Both isomers of arabinose were employed in this nutritional investigation of *Calvatia* species but neither of them promoted satisfactory growth. According to Lilly and Barnett (**1956**), from the distribution of the isomers of arabinose in organisms, it would be expected that L-arabinose would be utilized readily by more fungi than D-arabinose. In the case of *Calvatia* species, two of the strains, 1019 B and 766, grew better on L-arabinose, and two strains, 1018 F and 1020, were superior on D-arabinose.

In general, the 6 carbon sugars were utilized more readily by *Calvatia* species than the pentoses. However, the ability of the strains to use them for growth varied.

According to the results shown in TABLE I, fructose was easily assimilated by the four strains of *Calvatia* tested, but it was inferior to glucose. Fructose is also metabolized by microorganisms, the same way

as glucose, but while glucose is converted to glucose-6-phosphate by ATP in the presence of glucokinase, fructose is converted to fructose-1-phosphate in the presence of fructokinase. Nilsson (**1956**) observed that fructose-1, 6-diphosphate (an intermediate product of carbon metabolism) had a very striking growth promoting effect on *Boletus variegatus* and *Collybia velutipes*. He also found that this effect was reversed, above a certain concentration of the diphosphate, at least for *Boletus variegatus*.

Mannose was readily used by *Calvatia fragilis* 1020, but this fungus grew much better on glucose. The rate of utilization for this strain was slow during the first 14 days of incubation, but later on it increased. Limited growth took place using mannose by the strains of *Calvatia gigantea*, 1018 F, 1019 B and 766, and most of the growth was completed within 14 days.

All of the *Calvatia gigantea* strains grew poorly on galactose, but *Calvatia fragilis* 1020 had a satisfactory mycelial growth on this 6 carbon sugar. According to Fruton and Simmonds (**1959**), the ability of an organism to use galactose depends upon its ability to convert this hexose into a phosphorylated derivative of glucose able to enter the main respiratory pathways. Rhamnose was not able to satisfy the carbon requirement of *Calvatia* species. Even *Calvatia fragilis* 1020 which gave an appreciable growth on mannose was not able to utilize this carbon source. None of the strains tested was able to utilize sorbose. The toxicity of sorbose was mentioned by Lilly and Barnett (**1953**). Cochrane (**1958**) suggested that sorbose may interfere with a respiratory pathway of the organism.

Oligosaccharides. As can be observed from the data presented in TABLE I, cellobiose was one of the best carbon sources for *Calvatia* species. Strain 1018 F produced 30 per cent more mycelium, strain 1019 B, 50 per cent more, strain 766, 100 per cent more, and strain 1020 produced almost 200 per cent more mycelial growth in the presence of cellobiose than with the generally accepted glucose as a carbon source within the 28 day period. According to Reese and Levinson (**1952**) most of the fungi are able to split cellobiose to its constituent glucose residues. Analyzing the data on cellobiose utilization, *Calvatia fragilis* 1020 seemed to be superior to *Calvatia gigantea* 1018 F, 1019 B, and 766, in the production of the appropriate enzyme. Strain 1018 F showed a relatively low mycelial growth after 14 days incubation, but later on, the rate of cellobiose utilization increased. The result suggested that the involved enzyme was inducible.

A satisfactory growth was obtained using maltose as a carbon source in the medium for *Calvatia* strains. Le Mense et al. (**1947**) found that

maltose was utilized by almost every fungus he investigated, although quantitative differences between strains were common. In general, the weight of the mycelial growth was lower than that obtained using cellobiose, with the exception of strain 1019 B. This may be due to the lack of the necessary hydrolytic enzyme in the fungi involved. The smaller amount of mycelial growth using maltose could be explained by the fact that maltose is more easily hydrolyzed by autoclaving than is cellobiose. Consequently, a special precaution was taken to sterilize the medium containing maltose for a minimum of time in the autoclave.

Sucrose was not a good carbon source for *Calvatia* species. It could be that the organisms produced the hydrolyzing enzyme very slowly or in a small quantity, as both components of this disaccharide (glucose and fructose) produced a satisfactory growth when used separately. Apparently the glucose to fructose linkage was not easily broken. Bealing (**1953**) observed that invertase preparations catalyzed the transfer of fructofuranosyl groups not only to water, but also to various alcohols and sugars by transglucosidation. The possibility that the small yield of the four *Calvatia* strains grown in sucrose-containing medium was due to the slow production of invertase rather than to an inability to utilize the components of this sugar could be proved or disproved by the substitution of invert sugar. All of the four strains of *Calvatia* investigated produced a very good growth on invert sugar (which is a mixture of glucose and fructose with the components present in 1 to 1 ratio). This of course indicated that invertase can be produced rapidly. With the exception of strain 1018 F, all the strains produced an even greater mycelial growth using invert sugar than when glucose was used (in 28-day cultures). The authors feel that this can be explained by the effect of combined carbon sources. One constituent, glucose, acted as an "inducer," permitting a rapid growth on the other constituent, fructose.

Trehalose was utilized satisfactorily by the strains of *Calvatia*. Cochrane (**1958**) indicated that in all probability trehalose in fungi has the role of a translocateable reserve carbohydrate which is formed early in the metabolism and used up later.

Lactose and melibiose appeared to be poor carbon sources for the *Calvatia* strains studied. All four of them produced very little mycelia in the presence of these disaccharides. The failure of *Calvatia* species to utilize these carbon sources could be explained by the lack of the necessary hydrolytic enzymes, lactase or melibiase; or by the inability to utilize one of the component hexoses, galactose.

Only one trisaccharide, raffinose, was employed in this nutritional study of *Calvatia* species. Raffinose, which has one linkage similar to

that observed in sucrose and another as in melibiose, was utilized poorly by the strains examined. *Calvatia* species were apparently not able to produce melibiase, but a certain amount of invertase was formed by the organisms. Therefore, the small amount of mycelial growth which was produced by the fungi investigated (grown on raffinose) could be explained by the availability of fructose.

Polysaccharides. Data shown in TABLE I indicate that good mycelial weights were obtained by three strains of *Calvatia* species utilizing soluble starch. Strain 1018 F was not able to utilize this carbon source in an appreciable amount. Strains 1020 and 766 grew somewhat better on starch than they did on maltose.

The glycogen utilization in *Calvatia* strains was proportional to their ability to use starch as a carbon source. The mycelial growth resulting from the utilization of glycogen was more abundant than that observed on starch, especially in the case of *Calvatia fragilis* 1020 where it even surpassed the yield on cellobiose.

Dextrin was by far the best carbon source investigated. With the exception of strain 1018 F, *Calvatia* species were able to satisfy their carbon requirements most effectively on this polysaccharide. Each *Calvatia* strain tested responded in the same way to dextrin as they did to starch and glycogen. Therefore, the discussion concerning the ability to utilize starch and glycogen by these fungi is also valid for dextrin utilization. The quantitative differences between starch and dextrin as carbon sources, however, cannot be interpreted easily until the chemistry of these polysaccharides is better known, according to Cochrane (**1958**).

Inulin was poorly utilized by *Calvatia* species. Just a small amount of growth was observed by each strain. The insignificant amount of growth that resulted from the use of this carbon source could be explained by the few units of glucose present in inulin. Hawker (**1950**) reported that the inability of certain fungi to use inulin for growth was due to the failure to secrete the enzyme, rather than any inhibitory effect of the inulin itself.

Calvatia species were not able to use cellulose as a carbon source. Evidently they lacked the enzyme necessary to decompose this polysaccharide. The lack of cellulase formation by *Calvatia* species could be proved by the fact that cellobiose, the intermediate product of this polysaccharide, was one of the best carbon sources for these organisms. However, it should be mentioned that the technic used for testing the cellulose utilization of *Calvatia* strains was unsatisfactory. The ability to use this polysaccharide could be inhibited by many other factors, e.g., the insolubility in water of the powdered cellulose used.

SUMMARY

Calvatia species were able to utilize a variety of carbon sources when grown in Lindeberg's medium plus thiamin. The amount of growth varied with the carbon source and was dependent on the particular enzymatic ability of the organism involved.

Calvatia gigantea strain 1018 F grew best in the following carbon sources, listed in decreasing order: cellobiose, maltose, glucose, fructose, invert sugar, dextrin and mannose. A moderately good growth was obtained using glycogen, trehalose, sucrose, starch, and raffinose; while ribose, inulin, xylose, lactose, arabinose, sorbose, galactose, melibiose, cellulose, and rhamnose supported very little growth.

Calvatia gigantea strain 1019 B utilized dextrin, invert sugar, maltose, cellobiose, glucose, starch, trehalose, and glycogen, listed in the order of their decreasing effectiveness. Considerably less, but still available to the organism as carbon sources, were fructose, sucrose, galactose, ribose, and mannose. The organism grew poorly on media incorporating inulin, raffinose, arabinose, xylose, lactose, cellulose, rhamnose, melibiose, and sorbose.

Calvatia gigantea strain 766 produced good mycelial growth on dextrin, cellobiose, invert sugar, glycogen, starch, glucose, maltose, and trehalose, in that order. Somewhat lower yields were obtained in the presence of galactose, fructose, xylose, mannose, raffinose, lactose, and sucrose. Arabinose, cellulose, inulin, rhamnose, sorbose, and melibiose were poor carbon sources for this organism. Strain 766 did not grow in ribose.

Calvatia fragilis strain 1020 satisfied its carbon requirement effectively on dextrin, cellobiose, glycogen, invert sugar, glucose and starch listed in the order of their decreasing effectiveness. Galactose, maltose, mannose, trehalose, and fructose were less available for the organism. Poorer growth was obtained in the presence of sucrose, inulin, raffinose, ribose, lactose, xylose, melibiose, arabinose, cellulose, sorbose, and rhamnose.

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A LABORATORY PROCEDURE FOR THE CULTIVATION AND FRUCTIFICATION OF SPECIES OF HERICIUM

JOHN A. YURCHENCO AND GEORGE H. WARREN

(WITH 5 FIGURES)

During the course of investigations concerning the tumor-inhibiting property of naturally occurring botanical materials, it was observed that an aqueous residue prepared from a sporophore of *Hericium erinaceous* (Bull. ex Fries) Pers. showed activity against a transplantable tumor in mice. In view of this observation, it seemed desirable to study the growth and fructification of species of *Hericium* under controlled laboratory conditions. The anti-tumor properties of sporophore preparations of laboratory-cultivated *Hericium* spp. will be discussed elsewhere.

MATERIALS AND METHODS

The procedure employed was a modification of the method described by Tamblyn and DaCosta (**1958**). The enriched medium employed was prepared in the following manner: yellow-pine, maple shavings and finely decayed wood (beech, sycamore, maple, pine) were separately dried in a hot-air oven (125° C) and ground to a uniform size in a Waring blendor. The dried decayed woods were pooled in equal proportions by weight into a "complex" mixture. The representative lots were subsequently sterilized by autoclaving for 3 hours and then dried in a hot-air oven (100° C) for 6–12 hours. The yellow-pine, maple and "complex" sawdusts were mixed, respectively, in proportions of 1:1:2 by weight. To 100 g of this substrate the following "enrichment" medium was added: maize meal, 2.5 g; bone meal, 2.25 g; potato starch, 0.5 g; yeast (dried), 0.2 g; malt extract, 0.5 g; casein hydrolysate, 0.175 g; thiamine HCl, 0.003 g. The first four constituents of this medium were pre-mixed with a small amount of sawdust substrate and then added to the remaining bulk of the "complex" mixture. The last 3 ingredients were dissolved in tap water and added to the substrate by thorough mixing.

Partially decayed and intact dead limbs of maple trees 3 to 3.5 inches in diameter were obtained and cut into 6-inch lengths. The bark was removed and the wood cylinders were hollowed-out with a 2.5-inch bit

FIG. 1. Glass assembly culture jar showing log with fruiting body of *Hericium caput-ursi*.

to give a well 4 inches deep. These units were immersed in a solution of the "enrichment" medium in a dessicator jar and brought to a suitable moisture content (approximately 100%) under partial vacuum. The wells of the wood cylinders were packed with moist enriched "complex" sawdust mixture, placed on supports inside battery jars (7 × 10 inches) containing a small amount of water and covered with overhanging glass lids. The units were sterilized by autoclaving, cooled and the wells inoculated with cell suspensions harvested from potato dextrose agar

FIG. 2. Glass assembly culture jar showing log with a primary sporophore of *Hericium erinaceous* after 4 months. Temperature of incubation: 18–20° C.

slants with mycophil broth (BBL). The units thus prepared consisted of two pairs each, one of which contained cylinders of partially decayed wood and the other dried wood of normal density.

Under the conditions described above several strains of each of the following species were studied for the formation of fruiting bodies on the wood cylinders: *H. erinaceous* (Bull. ex Fries) Pers., *H. coralloides* Scop. ex S. F. Gray; *H. septentrionale* Fr.; *H. henningsii* Bres.; *H. abietis* Hubert; *H. caput-ursi* Fr. Cultures of these species, other than

a strain of *H. coralloides* isolated in our laboratory, were obtained from The New York Botanical Garden, the Forest Products Research Laboratories, England, and the Centraalbureau Voor Schimmelcultures, Baarn, Netherlands. All stock cultures were maintained on potato dextrose agar (Difco) in the dark at 26° C.

The jars were incubated in the dark with the various species at 26° C until luxuriant mycelial growth was evident. The assemblies were then transferred for the duration of the study to a room maintained at 18–20° C. Abundant diffused light was provided and a relatively high humidity and air circulation maintained by bubbling air through a water reservoir and hence into the jars through rubber tubings connected to side-arms piercing the lids of the assemblies (FIG. 1).

RESULTS

Of the *Hericium* species studied, none produced fruiting bodies on the dense wood and only four of the species produced fruiting bodies on the partially decayed wood after 9 months of observation. Although the cultures showed good growth within the wells of the hard wood cylinders, none penetrated the dense woody structure and mycelial growth appeared externally only at points of fissure. In sharp contrast all of the representative strains growing on the partially decayed specimens developed luxuriantly, enveloping the external surfaces with a solid sheet of mycelium. However, in spite of this luxuriant mycelial growth, 7 out of the 11 strains (representing 6 different species of *Hericium*) failed to produce fruiting bodies and eventually ceased to grow.

The decayed logs which produced fruiting bodies showed the following sequence of events: the initial sign of sporulation was the appearance of a condensed area of growth at several points with subsequent elevation, a deepening of color from white to golden yellow and finally, the formation of dome-like projections. Shortly thereafter, in the case of *H. coralloides* and *H. caput-ursi*, a short pileus was formed, at which point the fruiting bodies consisted of branching convoluted stalks bearing at their tips pendant tufts of pointed teeth. *H. coralloides* and *H. septentrionale* formed short stipes during the initial stages of growth, but these were rapidly integrated into the main bulk of the growing sporophores. *H. erinaceus* initially presented a smooth to slightly irregular surface with a white to yellowish color. As the immature fruiting body continued to grow, it lost its smooth appearance and eventually became a large, fleshy, convoluted mass, the surface of which presented irregular rows of soft spines or teeth. FIG. 2 illustrates the general appearance of

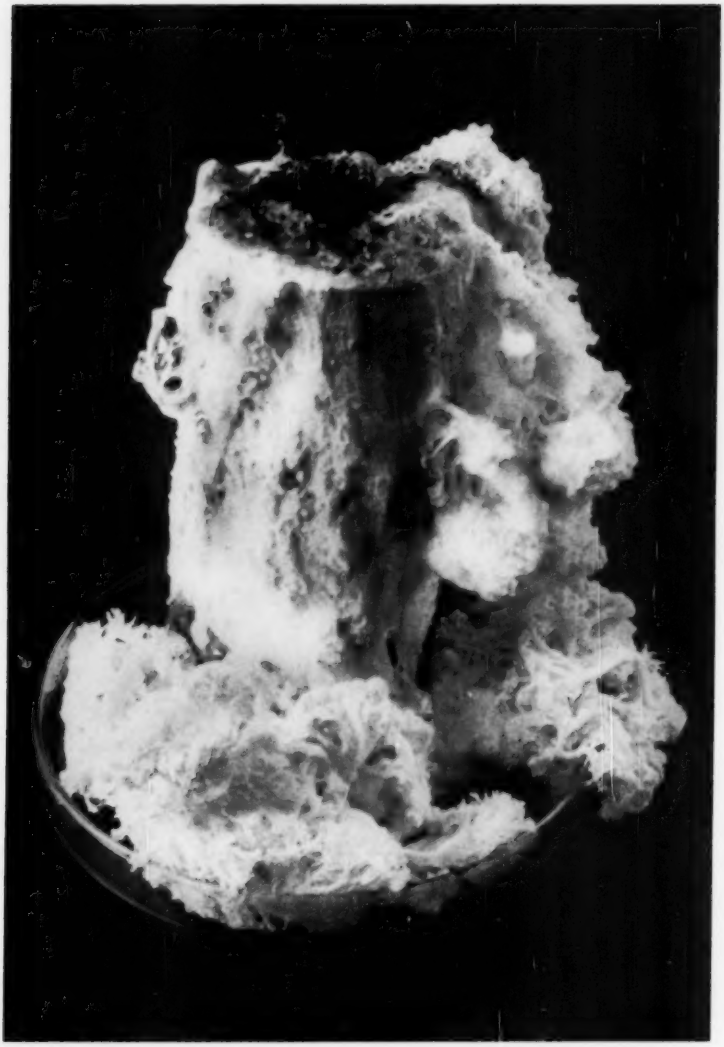

FIG. 3. Primary fruiting bodies of *Hericium erinaceus* after 8 months. Temperature of incubation: 18–20° C.

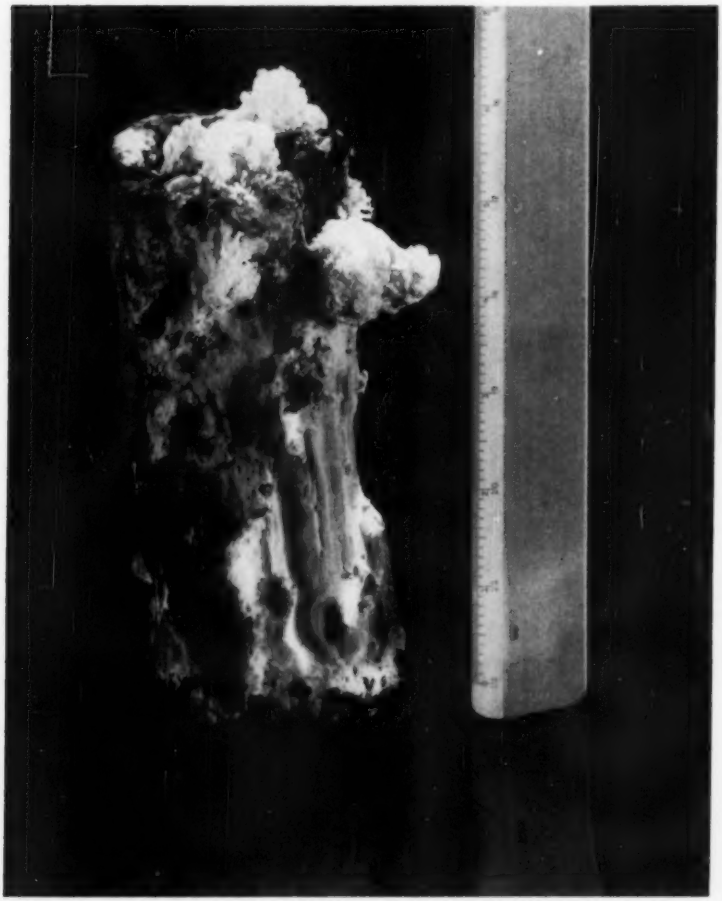

FIG. 4. Secondary fruiting bodies of *Hericium erinaceous* 5 weeks after harvesting of initial sporophores. Temperature of incubation: 18–20° C.

a primary sporophore of *H. erinaceous* after 4 months incubation at 18–20° C. After an additional 4 months incubation the growth was harvested and was found to weigh 55 g (FIG. 3). A second preparation is shown in FIG. 4. This unit shows secondary fruiting bodies of *H. erinaceous* approximately 5 weeks after the initial bodies had been harvested. FIG. 5 shows the appearance of *H. caput-ursi* approximately 4–5 weeks after the initial mass had been removed. The pileus with terminal branching stalks may be readily seen.

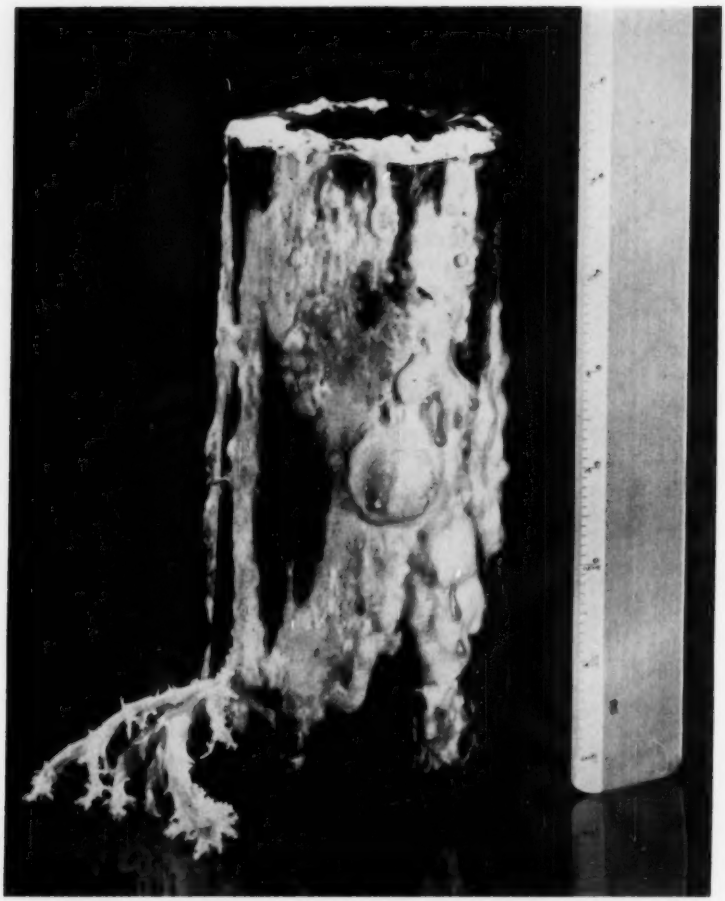

FIG. 5. Secondary fruiting body of *Hericium caput-ursi* 4–5 weeks after removal of initial sporophore. Temperature of incubation: 18–20° C.

The data in TABLE I show that the species required a minimum of 2 weeks incubation at 26° C before luxuriant mycelial growth became evident in the enriched sawdust medium. The time required for the appearance of the initial fruiting body varied from 5 to 13 weeks. *H. septentrionale* proved to be exceptional in that the sporulating body appeared and matured sooner and was considerably larger than those of the remaining species. Although the other species of *Hericium* produced initial bodies after approximately the same length of time, differ-

TABLE I

GROWTH RATES OF MYCELIA AND FRUITING BODIES OF HERICIUM SPECIES UNDER LABORATORY CONDITIONS

Species	Mycelial growth (weeks)	Fruiting* body (weeks)	Time† of harvest (weeks)	Weights of fruiting bodies (g.)	
				Wet	Dry (*)
H. erinaceous (A)	2	11	38	22.6	2.6
H. erinaceous (B)	2	13	22	51.2	5.2
H. coralloides	2	10	8	10.8	1.0
H. septentrionale	2	5	7	87.8	8.4
H. caput-ursi	2	13	14	3.2	0.68

* Appearance of initial fruiting body.
† Harvested after appearance of initial body.
(*) Lyophilized.

ences may be noted between the final wet weights of the fruiting bodies. In the case of *H. coralloides* and *H. caput-ursi* the harvesting of fruiting bodies was dictated by the general appearance of the branching stalks. At the times indicated in TABLE I the fruiting bodies began to show degenerative changes, i.e. browning and loss of rigidity of the stalks. However, the wood cylinders continued to produce new growths subsequent to the removal of the older fruiting bodies.

DISCUSSION

The experimental studies of Badcock (**1941**, **1943**) and Tamblyn and DaCosta (**1958**) established certain requirements in the laboratory for the cultivation and fructification of wood-rotting fungi. Some preliminary studies in our laboratory with several species of *Hericium* using their methods proved only partially successful. A number of fruiting bodies were grown but none were sufficiently large to provide the desired quantity of material for further investigation. In addition, the assemblies prepared according to the procedures described by them became readily contaminated during manipulation. In view of these difficulties the method of Tamblyn and DaCosta (**1958**) was modified. Our method required little or no handling of the assemblies once the cultures were actively growing. However, considerable time was required before suitable mature specimens became available. The reasons for the failures with the majority of the representative strains studied are not understood. It is possible that some of these cultures may have been sexually incapable of producing sporophores or that the experimental and environmental conditions were unsuitable.

SUMMARY

A method is described for the cultivation and fructification of species of *Hericium* in laboratory cultures. Seven different species of *Hericium* were studied for the formation of fruiting bodies on wood cylinders. Although none of the species produced fruiting bodies on nondecayed wood, luxuriant growths were found for four species (*H. caput-ursi, H. erinaceous, H. coralloides, H. septentrionale*) when partially decayed wood and other experimental conditions were employed.

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THE GENUS SCHIZOPHYLLUM

Wm. Bridge Cooke

INTRODUCTION

Specimens of fungi assignable to the genus *Schizophyllum* have been collected in all parts of the world where woody plants grow. They have aroused the interest of people from very early times as evidenced by the fact that primitive people in widely scattered areas know *S. commune* by specific common names and even use it as a food or as a type of "chewing gum." Specimens of *Schizophyllum* have aroused the interest of collectors ever since fungus fruit bodies have been collected and preserved in herbaria.

Because of the similarity of species of *Schizophyllum* to agarics, especially in the fresh or revived condition, mycologists have classified *Schizophyllum* in the Agaricaceae (Killermann, **1928**; Kauffman, **1918**; etc.) or in the Tricholomataceae of the Agaricales (Singer, **1949**). There has been some discussion (reviewed by Lohwag, **1941**) in which it has been attempted to derive the genus from *Skepperia*, a stipitate, spathulate, stereaceous fungus usually assigned to the Thelephoraceae (*sensu lato*), by assuming that a lateral fusion of pilei took place.

DEVELOPMENTAL MORPHOLOGY

The observation of numerous sporophores, both from herbarium specimens and from cultures, indicates that the fruit body is initially an inverted cup with a smooth, active, hymenium covering the entire lower surface. As the cup enlarges peripherally, certain segments grow more rapidly than others. As the principal radiating segments elongate, they also expand laterally. Both the radial and lateral growth patterns are symmetrical. If, as happens in some cases, the point of attachment of the pileus is central, a perfectly round fruit body will develop. This will be divided into segments for almost the length of the radius of the pileus. Some pilei will show these segments as separate branches, the "digitatum" or "radiatum" type of pileus. Other pilei will develop so that these segments will be shown to be separate only after careful observation or by observing tangential sections through the margin or mid-parts of the pilei. Linder's Plate 34, fig. 3 (Linder, **1933**), shows this type of devel-

opment best. Lines of major development branch dichotomously so that each of these primary divisions of the pileus may become partially divided 2, 4 or 8 times. The secondary, tertiary and other successive partitionings of the hymenophoral branches do not completely split the context, and may even be so shallow that the "brevilamellatum" type of development occurs. A large specimen among those borrowed from the Royal Botanic Gardens, Kew, of the type referred to by Raper and Krongelb (**1958**) as "coralloid," collected from a special paper-straw thatched roof, showed this character very clearly. Other collections show it upon careful inspection, the smaller the receptacle the smaller the central area with a smooth, active hymenium. The other species of *Schizophyllum* also show this character. These observations confirm the view of Essig (**1922**) who assigned the genus to the Thelephoraceae.

CYTOLOGY AND GENETICS

Ehrlich and McDonough (**1949**) described the cytological phenomena observed in the basidia of *S. commune*. They found a pattern similar to that of other Basidiomycetes. Briefly, the basidium is at first binucleate, nuclear fusion takes place followed by meiosis. Each of the four resulting nuclei migrates to the base of a sterigma and one nucleus migrates into each basidiospore. Within the basidiospore each nucleus divides mitotically so that two nuclei lie in the apex of the spore before it is discharged from the basidium, at least in the material these investigators studied. They found the diploid number of chromosomes to be 6, the haploid number 3. Extensive genetic studies, especially of *S. commune*, have been undertaken by Raper and his students. Some of these are cited in the bibliography. Reference is made to cultural studies reported by Raper in connection with those species which have been received in viable condition.

TAXONOMY

Numerous studies have been made on *Schizophyllum*. The species have been described in various works as material was received by different authors such as Fries, Patouillard, Berkeley, and others. Linder (**1933**) presented a detailed and thorough analysis of the species found in the Western Hemisphere. Specimens examined by him were those filed in the Farlow Herbarium.

In the development of a project to determine the breadth of genetic phenomena in the genus *Schizophyllum*, Raper and Krongelb (**1958**) obtained 58 collections of this genus from such widespread places as Australia, Russia, South Africa, California, and intermediate places

between longitude 60° North and 45° South. This material, kindly supplied to the writer by Dr. Raper, served as a catalyst for a taxonomic revision of the genus.

Raper had expected, because of the wide geographic distribution of the material he studied, that more than one species might be included. Actually, only one of the species considered valid here was represented in these collections.

In a report of identification of collections, C. G. Lloyd (1916) remarked: ". . . I think there is in reality only one species and but very few collections are entitled to a separate name even as a variety." In the only treatment at the monographic level found to date, Linder (1933) recognized 6 species for the Western Hemisphere. He wrote: "The problem narrows down to a study of the microscopical characters that may aid in separating species."

In a search of more than 40 herbaria for specimens of this genus, nearly 4000 collections have been examined. The herbaria from which these collections were borrowed are listed in TABLE I together with the code symbol for each herbarium (Index Herbariorum, 1956) and the number of specimens examined from each. Where the herbarium is not listed in Index Herbariorum, a code is improvised in the table.

Among the binomials listed there are more than 20 which have been published and three used as herbarium names only. In addition there is at least one validly published subspecific taxon. It may be noted that in the 58 collections obtained by Raper, only one species was involved according to almost any species concept which might be applied.

Linder recognized two groups within the species he listed although he did not apply names to these at any subgeneric level. Singer (1949) named these groups Stirps *Commune* with well differentiated subhymenium including "*S. commune* Fr.; *S. radiatum* (Swartz ex) Fr. (if not identical with *S. commune*); *S. brevilamellatum* Linder; *S. fasciatum* Pat." and Stirps *Umbrinum* with subhymenium undifferentiated including *S. umbrinum* Berk.; *S. leprieuri* Linder. On the basis of observations made by the writer, all species described in this treatment have a differentiated subhymenium although this may not be too clearly evident in all specimens.

In recent years a number of titles have appeared in the literature of agricultural botany in which the generic name *Schizophyllum* appears. Several new species have been proposed in this genus. Upon checking the source of such novelties it has been found that this name is in use for a genus of centipedes in the suborder *Diplopoda*, division *Myriapoda*, Phyllum *Arthropoda*.

TABLE I

HERBARIUM SOURCES OF SCHIZOPHYLLUM COLLECTIONS

Code	Herbarium	Number of specimens examined
BPI (NFC)	National Fungus Collections (Including the C. G. Lloyd, National Museum, and Forest Pathology collections.)	1162
NY	New York Botanical Garden	359
FH	Farlow Herbarium (Including the General, Patouillard, von Hoehnel, Curtis, and Burt collections.)	275
K	Royal Botanic Gardens, Kew	275
F	Chicago Museum	195
S	Naturhistoriska Riksmuseet, Stockholm	194
L	Rijksherbarium, Leiden	112
CUP	Cornell University Herbarium (Including Fairman, China, Puerto Rico, Venezuela, Korf, Atkinson, and General collections.)	111
MICH	University of Michigan, Ann Arbor	100
Raper	John R. Raper, Harvard Biological Laboratories	95
UC	University of California, Berkeley	88
BO	Herbarium Bogoriense, Bogor, Indonesia	83
PRE	National Herbarium, Pretoria	64
DAOM	Science Service, Ottawa	51
TRT	University of Toronto, Toronto	46
ILL	University of Illinois, Urbana	45
WIS	University of Wisconsin, Madison	43
BR	Jardin Botanique de l'État, Bruxelles	42
TENN	University of Tennessee	34
B	Botanisches Museum, Berlin-Dahlem	32
FLAS	University of Florida, Gainesville	31
PAC	Pennsylvania State University, University Park (Including the L. O. Overholts collection.)	30
MEL	National Herbarium of Victoria, Melbourne	27
WSP	Washington State University, Pullman	24
IA	State University of Iowa, Iowa City	20
MELFP	Australia Forest Products Laboratory, Melbourne	19
OS	Ohio State University, Columbus	18
CINC	University of Cincinnati, Cincinnati	16
PC	Musée National d'Histoire Naturelle, Paris	15
OSC	Oregon State University	14
(WBC)	Herbarium of Wm. Bridge Cooke, Cincinnati	14
NCU	University of North Carolina, Chapel Hill	14
DAVFP	Dominion Laboratory of Forest Pathology, Victoria, B. C.	10
(VP)	Herbarium of Victor Potter, Michigan	10
NSW	National Herbarium of New South Wales, Sydney	10
GA	University of Georgia, Athens	6
(UIFP)	University of Idaho, Dept. of Forest Pathology, Moscow	5
(NZPD)	New Zealand Division of Plant Diseases, Auckland	5
NO	Tulane University, New Oreleans	5
(KNS)	Canada Agriculture Research Station, Kentville	5
HCIO	Division of Mycology, New Delhi	4
(LAO)	Dept. of Forests, Territory of Papua and New Guinea	2
(MELU)	University of Melbourne	2
RM	University of Wyoming, Laramie	1
SDU	University of South Dakota, Vermillion	1
	Total specimens observed	3714

SCHIZOPHYLLACEAE Roze, Bull. Soc. Bot. Fr. **23**: 51, 108. 1876. (as Schizophyllacées)

Schizophylleae Henn., in Engl. & Prantl, Nat. Pfl.-fam. 1**: 221. 1898. (as Tribus)

With the characters of the type genus; with both hyaline and colored spores.

Type genus: *Schizophyllum* (Fr.) Fr.

This genus was assigned by Singer to the Tricholomataceae, thus relegating the family and tribe to synonymy. He is followed in this by the editors of the 12th edition of Engler and Prantl (Melchoir and Werdermann, **1954**). Gäumann and Dodge, however, assign this tribe to the Agaricaceae, but they suggest that possibly a more natural disposition would be in or near the Cyphellaceae, following the interpretation of the structure of the fruit body given by Essig. Kauffman placed it in his Tribe Marasmieae of the Agaricaceae.

The present writer has suggested elsewhere (Cooke, **1961**) that he would place this genus near the cyphellaceous fungi. His disposition of this genus is in the family Schizophyllaceae, in the suborder Porotheleineae of the Polyporales.

SCHIZOPHLLUM Fr., Syst. Mycol. **1**: 330. 1821.

[*Lithodermyces* Batt., Fung. Hist. 62. 1755.]

[*Hyponeuris* Paul, Ic. 75. 1793–1812.]

[*Schizophyllus* Fr., Obs. Mycol. **1**: 103. 1815.]

[*Flabellaria* Pers., Champ. Comest. 105. 1818.]

[*Scaphophorum* Ehrh., Horae Phys. Berol. **1**: 94. 1820.]

Apus Nees ex S. F. Gray, Nat. Arr. Brit. Pl. **1**: 617. 1821.

Schizonia Pers., Mycol. Europ. **3**: 14. 1828.

Rhipidium, Wallr. Fl. Cr. Germ. **2**: 742. 1833.

Hyponeuris Paulet ex Earle, Bull. N. Y. Bot. Gard. **5**: 411. 1909.

Schizophyllus Fr. ex Murrill, North Amer. Fl. **9**(4): 237. 1915.

Pileus suborbicular to flabelliform, simple to densely imbricate; sessile or attached by a marginal, eccentric or central stipe-like base or crown; white to brown, coriaceous, thin to somewhat thickened; in cross section, at points of optimum development, divided more or less distinctly into four areas of tissue; (1) surface layer 100–1000 μ thick, a trichoderm formed of loosely to densely interwoven hyphae; hyaline to brown, thick-walled hyphae arranged singly or in small to large loose fascicles which branch and anastomose, arising from the context. (2) Context 100–1200 μ thick, composed of densely interwoven hyphae with thick walls, narrow lumen, hyaline to brownish walls, and appearing gelatinous in

cross section. (3) Subhymenium usually about 10 μ wide, composed of narrow hyphae. (4) The hymenium, composed of basidia and sometimes cystidia. Clamp connections present on hyphae of context, subhymenium, and bases of the basidia, not always readily apparent.

Pileus at first a small cupulate body, quickly developing a smooth hymenium; hymenophore soon cleft at the margin, each segment developing more or less rapidly in two directions; as the cleft segment elongates, it branches dichotomously and additional units may be inserted between the primary branches; as the cleft segment and its branch units broaden, they match the growth of adjacent segments and branches, eventually producing a compound split-gill appearance. Upon drying, the margins of the cleft portions curl inwardly, opening upon being remoistened. Cleft hymenophoral area developing indefinitely on the under side of context tissue adjacent to and continuous with the context tissue of the pileus; in cross section, hymenophoral branches rebranched in pairs. Near base of pileus 4–8–16 such pairs in each unit, or more than 4, 8, or 16 branches in each unit; in central part of pileus 2, 4, or 8, usually 4 or 8 branches in each unit; at margin 2, 4, or 8 branches in each unit, rarely 1, usually 2 or 4 such branches in each separate unit; inserted units showing 2, 4, or 8 branches in each unit.

Hymenium composed of basidia and sometimes cystidia; basidia clavate, usually 4-sterigmate. Spores hyaline, narrowly ellipsoid or long ovate to cylindrical or suballantoid, smooth, with no reaction in Melzer's reagent, KOH or $FeSO_4$.

Type species: *S. commune* (Fr.) Fr.

KEY TO SPECIES

1. Spores yellow brown (under the microscope).....Genus *Phaeoschizophyllum*
   .....*P. leprieuri*
1. Spores hyaline (under the microscope).....Genus *Schizophyllum*
   2. Cystidia present.....*S. fasciatum*
   2. Cystidia absent.....3
3. Sporophore with distinct halo of white to grey hyphae around point of insertion on substratum.....4
3. Sporophore without such basal hyphae.....5
   4. Sporophore white.....*S. palmatum*
   4. Sporophore golden brown, fading gray in age.....*S. umbrinum*
5. Sporophore brown, spores up to 9 μ long.....*S. brasiliense*
5. Sporophore white to grey, spores reaching 7.5 μ long.....*S. commune*

SCHIZOPHYLLUM COMMUNE (Fr.) Fr., Syst. Mycol. **1**: 330. 1821.
[*Agaricus alneus* Linn., Sp. Pl. ed. 1, **2**: 1176. 1753.]
[*?Schizophyllum miia* Scop., Hist. Nat. **4**: 147. 1769.]
[*Agaricus multifidus* Batsch, f. 126, 1783.]

[*Agaricus radiatus* Swartz, Prodromus 148. 1788.]

[*Schizophyllus commune* Fries, Obs. Mycol. **1**: 103. 1815.]

[*Scaphophorum agaricioides* Ehrh., Horae Phys. Berol. **1**: 94. 1820.]

Schizophyllum flabellare Fr., Afz. Guin. t. xi, 25. 1837.

?Schizophyllum exiguum Miq., Bull. Neerl. **1839**: 152. 1839.

Schizophyllum radiatum (Swartz) Fr., Nov. Symb. Mycol. 41. 1855.

Schizophyllum commune var. *maxima* Rab. in Rabenhorst's Fungi europaei 705. 1864.

Schizophyllum commune var. *incisum* de Thümen, in de Thümen, Fungi austriaci 1109. 1874.

Schizophyllum multifidum (Batsch) Fr. in Berk., F. Ceylon n. 430. 1875.

Schizophyllum commune forma *lobatum* Sacc., in D. Sacc., Mycotheca veneta 795. 1878.

Schizophyllum commune var. *palmatum* Debeaux, Rev. Mycol. **1879**: 152. 1879.

Schizophyllum alneum (L.) Schroet., Pilzfl. Schles. **1**: 553. 1889.

Schizophyllum murrayi Massee, Jour. Bot. **30**: 164. 1892.

Schizophyllum egelingianum Ell. & Ev., Bull. Torrey Bot. Club **22**: 439. 1895.

Schizophyllum lobatum Went, Ber. Deutsch. Bot. Ges. **1896**: 158. 1896.

Schizophyllum flabellare Ell. & Kell., non Fr., nom. nud. in G. V. Nash, Pl. of Florida 2044 (1904?).

Hyponeuris alneus (L.) Earle, Bull. N. Y. Bot. Gard. **5**: 412. 1909.

Schizophyllum vulgare Lloyd, nom. nud., Mycol. Writ. **3**: Let. **29**: 4. 1912.

?Schizophyllum pavonium Ellis, nom. nud., in Murr., Mycologia **4**: 214. 1912.

Schizophyllum album Rick, Broteria, Ser. Bot. **17**: 111. 1919.

Schizophyllum brevilamellatum Linder, Am. Jour. Bot. **20**: 559. 1933.

Pileus 1–5 cm deep and 1–6 cm wide, solitary to slightly or densely imbricate, sessile or attached by a lateral extension of the margin which at times may form an elongated stipe-like base, flabelliform; margin varying from weakly scalloped to slightly incised, deeply cleft or split so deeply as to digitately divide the pileus (splitting to about $\frac{2}{3}$ the depth of the pileus); surface villose, a zonate to azonate trichoderm, the hairs frequently matted, white, pallid, brownish, brown ("wood brown" or "fawn"), and in age gray, dark gray or blackish. Context (168–)320–

640(–760) μ thick, occasionally up to 1300 μ thick, hyaline to brownish, especially discolored in a thin peripheral zone.

Hymenophore at first a disc with a smooth hymenium, becoming split radially as regularly spaced groups of hyphae grow more rapidly than intervening groups, the more rapidly growing groups forming hymenophoral branches which branch dichotomously as growth outwardly from the center proceeds, forming 2, 4, 8, or 16 hymenophoral units. Adjacent hymenophoral units appearing as split "lamellae" reaching (360–) 800–1400(–1700) μ deep, whitish to buff colored, greyish or brownish, hirsute on the abhymenial side from specialized abhymenial hairs; when context is very thick, hymenophoral units may be reduced to 36–108 μ broad at the edge, (81–)118–225 μ broad at the base, including the adjacent lamella-like walls.

Abhymenial hairs about 3.5–5.5(–7.2) μ, hyaline to slightly brownish colored, thick-walled, of various lengths, often granular-incrusted over outer third, forming a trichoderm. At margin of hymenophoral units abhymenial hairs hyaline, thin-walled, simple or somewhat swollen terminally, or short bifurcate or weakly acanthophysoid at the apex, in younger areas 25–50 μ long, quickly indistinguishable from hyphae of surface trichoderm. Context hyphae 2.5–6.0 μ in diameter, thick-walled, clamped, giving rise to the subhymenium; no gelatinous hyphae present. Subhymenial hyphae 1.5–3.0 μ in diameter, clamps present.

Hymenium (16–)20–25(–30) μ thick. Basidia 15–20 × 5–7 μ, but varying either longer or narrower or both, 4-sterigmate; sterigmata 2.5–3 μ long; cystidia none.

Spore deposit white; spores 4–7.5 × 1.5–2.5(–3) μ, hyaline under the microscope, smooth, suballantoid in profile, narrowly oblong to cylindric (rarely long-ovate) in face view, apiculate.

Habitat: Usually on wood and herbaceous materials of at least the following species: *Abies* sp., *A. balsamea, A. concolor, A. fraseri, A. grandis, Acacia* spp., *A. baileyana, A. binervata, A. dealbata, A. decurrens, A. farnesiana, A. harpophylla, A. karroo, A. koa, A. longifolia, A. melanoxylon, A. mollissiana, Acer* spp., *A. circinatum, A. dasycarpum, A. glabrum, A. macrophyllum, A. negundo, A. pennsylvanicum, A. platanoides, A. pseudoplatanus, A. rubrum, A. saccharinum, A. saccharum, Aesculus* sp., *A. hippocastanum, Agathis australis, Agave* sp., *A. sisaliana, Ailanthus altissima, Albizzia* sp., *A. falcata, A. julibrissin, Aleurites fordii, A. moluccana, Alnus* spp., *A. glutinosa, A. incana, A. rhombifolia, A. rubra, Amango* sp., *Amelanchier alnifolia, Anisophyllea laurina, Anisoptera thurifolia, Ananas comosa, Anona glabra, Araucaria* sp. (cone and cone scale), *A. bidwillii, A. cookii, Areca catechu, Arenga saccharifera, Armeniaca vulgaris, Avicennia* sp., *Baccharis halmifolia,*

Bambusa sp. (pots), *Bambusa*, sp., *B. spinosa*, *B. vulgaris*, *Bauhinia* sp., *Beilschmeidia tawa*, *Betula* spp., *B. alba*, *B. lenta*, *B. lutea*, *B. papyrifera*, *B. populifolia*, *B. verrucosa*, *Blumea balsamifera*, *Brachystegia apiciformis*, *Bursera* sp., *B. simaruba*, *Calamus* sp., *Carpinus* spp., *C. betula*, *C. caroliniana*, *Carya* spp., *C. alba*, *C. laciniosa*, *C. minima*, *C. ovata*, *C. pecan*, *Cassava* sp., *Cassia* sp., *C. bicapsularis*, *C. lindheimeriana*, *C. sieberiana*, *C. strobilacea*, *Cassinia* sp., *Celtis kraussiana*, *C. philippinensis*, *Cercoxylon* sp., *Chamaecyparis thyoides*, *Cinnamomum camphorea*, *Citrus* sp., *C. aurantiifolia*, *C. reticulata*, *Cocos* sp., *C. nucifera*, *Corylus avellana*, *Crotelaria saltiana*, *Cyclostemon* sp., *Cryptostegia* sp., *Dacyridium cupressinum*, *Davylia abyssinica*, *Dichrostachys nutans*, *Diospyros* sp., *D. kaki*, *D. virginiana*, *Dicksonia* sp., *Dumetorum eopedem*, *Elaphorinia* sp., *Erica* sp., *Eucalyptus* sp., *E. globulus*, *Erythrina* sp., *E. speciosa*, *Excoecaria agallocha*, *Fagara coco*, *Fagus* spp., *F. grandifolia*, *F. silvatica*, *Ficus* sp., *F. carica*, *F. nota*, *F. ulmifolia*, *Fraxinus* sp., *F. excelsior*, *Galbaluminia baccata*, *Genista praecox*, *Gleditsia* sp., *G. horrida*, *G. sinensis*, *G. triacanthos*, *Gliciridia sepium*, *Gossypium* sp. (bolls), *Grevillea robusta*, *Guettarda* sp., *Haronga madagascarensis* (latex), *Hevea* sp., *H. brasiliensis*, *Hura* sp., *Hakea sericea*, *Ilex opaca*, *Inga laurina*, *Instia bijuga*, *Ipomoea batatas* (root), *I. fistulosa*, *Iva?* sp., *Jacaranda* sp., *Juglans* spp., *J. cinerea*, *J. nigra*, *J. regia*, *Juniperus* sp., *J. bermudiana*, *J. virginiana*, *Khaya nyassica*, *Larix europaea*, *Laura canescens*, *Leucaena glauca*, *Leucodendron argenteum*, *Liquidambar styraciflua*, *Liriodendron tulipifera*, *Luffa cylindrica*, *Lupinus arboreus*, *Macaranga tamarindus*, *Maclura pomifera*, *Macropiper excelsum*, *Magnolia glauca*, *Mangifera* spp., *M. altissima*, *M. indica*, *Manihot glassnowii*, *M. utilissima*, *Mimosa* sp., *Morus alba*, *Musa* sp., *M. sapientum*, *Myrica* sp., *Nerium oleander*, *Nyssa* sp., *N. silvatica*, *Ochroma lagopus*, *Olea* sp., *Olinia cymosa*, *Opuntia* sp., *Palmetto parviflora*, *Pandanus* sp., *Parashorea plicata*, *Paulownia tomentosa*, *Persea americana*, *P. gratissima*, *Phoenix dactylifera*, *P. reclinata*, *Phyllostachys bambusoides*, *Picea* spp., *P. excelsa*, *P. glauca*, *P. rubra*, *P. sitchensis*, *Pinus* sp., *P. contorta*, *P. echinata*, *P. edulis*, *P. elliottii*, *P. insignis*, *P. oocarpa*, *P. resinosa*, *P. rigida*, *P. sabiniana*, *P. sylvestris*, *P. strobus*, *P. taeda*, *P. virginiana*, *Pipturus arborescens*, *Pistachia chinensis*, *P. weinmannifolia*, *Platanus occidentalis*, *Poinciana gilliesii*, *P. regia*, *Polyalthia* sp., *Populus* spp., *P. alba*, *P. balsamifera*, *P. deltoides*, *P. fremontii*, *P. tacamahaca*, *P. tremula*, *P. tremuloides*, *P. trichocarpa*, *Prioria papaifera*, *Prosopis* sp., *P. vidaliana*, *Protium* sp., *Prunus* spp., *P. amygdalus*, *P. armeniaca*, *P. avium*, *P. domesticus*, *P. pennsylvanicum*, *P. salicina*, *P. serotina*, *P. serrulata*, *P. virginiana*, *Pseudotsuga menziesii*, *Pterocarpus indicus*,

Pyrus sp., *P. communis*, *P. malus* (including fruits), *Quercus* spp., *Q. agrifolia*, *Q. chrysolepis*, *Q. coccinea*, *Q. garryana*, *Q. laurifolia*, *Q. lobata*, *Q. montana*, *Q. myrtifolia*, *Q. nigra*, *Q. palustris*, *Q. pedunculata*, *Q. rubra*, *Q. spinosa*, *Q. virginiana*, *Raphia vinifera*, *Rhamnus alpinus*, *R. purshiana*, *Rhizophora mangle*, *Rhus* sp., *R. glabra*, *R. hirta*, *R. osbeckii*, *R. toxicodendron*, *R. typhina*, *R. vernix*, *Ricinus* sp., *Robinia pseudacacia*, *Roystonea regia*, *Sabal palmetto*, *Saccharum officinarum*, *Salix* spp., *S. capraea* var. *pendula*, *S. fragilis*, *S. humboldtiana*, *S. laevigata*, *S. nigra*, *Sambucus* spp., *S. canadensis*, *Sapium luzonicum*, *S. merrillianum*, *Sarothamnus* sp., *S. scoparius*, *Sassafras variifolium*, *Schinus molle*, *S. terebinthifolius*, *Schizostachyum* sp., *Sequoia sempervirens*, *Serenoa serrulata*, *Shorea mindanoensis*, *Sloanea caribbaea*, *Sorbus americana*, *Spondias lutea*, *S. mombin*, *Swietenia* sp., *Tamarindus indica*, *Tamarix* sp., *Taxodium distichum*, *Terminalia comantana*, *Theobroma cacao*, *Thuja occidentalis*, *T. plicata*, *Tilia* spp., *T. americana*, *T. parvifolia*, *T. platyphylla*, *Tsuga canadensis*, *T. heterophylla*, *Ulmus* spp., *U. americana*, *U. glabra*, *U. pumila* var. *arborea*, *U. scabra*, *Umbellularia californica*, *Vaccinium australe*, *V. pennsylvanicum*, *Vitex lucens*, *Vitis* spp., *Wisteria sinensis*, *Yucca* sp., *Zea mays*.

In addition the following substrata are host to this fungus: Aakken, Amarillo, Caballa, Cabbage Palm, Cactus, Chilicnate, Coconut shell, Gandavum, Leguminous tree, Lotus tree, Keyoki, Mangrove, Mesquite, Orchid, Palms, Rubber tree, She-Oak, Palm Fruit, Papaya, Proteinum, Salai Wood, Stranick roofing, wood of a grapefruit cask, under side of a diving board, wooden silo in 2 year old silage, latex of *Heronga madagascarensis*, bottom of a wooden slop pail, on dregs in a bottle of tincture of gentian, on whale bone (verbal report), on clinical materials from living patients (toe nail and sputum).

Specimens examined: United States: Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming; Canada: Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Quebec, Saskatchewan; British Honduras, Canal Zone, Costa Rica, Guatemala, Honduras, Mexico, Nicaragua, Panama, El Salvador; Bahamas, Bermuda, Barbadoes, Cayman Islands, Cuba, Dominica, Grenada, St.

Jan, St. Lucia, St. Vincent, Trinidad, Guadeloupe, Haiti, Hispaniola, Jamaica, Mauritius, Puerto Rico, Dominican Republic, Surinam, Virgin Islands; Argentina, Bolivia, Brazil, British Guiana, Chile, Colombia, Dutch Guiana, Ecuador, French Guiana, Galapagos Islands, Paraguay, Peru, Uruguay, Venezuela; Austria, Belgium, Bulgaria, Canary Islands and Madeira, Caucasus, Czechoslovakia, Denmark, England, Finland, France, Germany, Greece, Holland, Hungary, Italy, Jugoslavia, Latvia, Lithuania, Luxembourg, Norway, Poland, Portugal, Roumania, Russia, Spain, Sweden, Switzerland, Transylvania, Turkey; Algeria, Belgian Congo, British East Africa, Camerouns, Ethiopia, Fernando Po, French Congo, Gambier, Gold Coast, Kenya, Madagascar, Mauritius, Mozambique, Natal, Nigeria, Northern Rhodesia, Nyassaland, Portugese East Africa, Rhodesia, Seychelles Islands, Sierra Leone, Sudan, Tchad, Tunis, Uganda, Union of South Africa, West Africa; Andaman Islands, Burma, Ceylon, China, Cyprus, Formosa, French Indo-China, India, Iran, Israel, Japan, Malaya, Okinawa, Siberia, Thailand; Admiralty Islands, Australia, Anietum, British North Borneo, Caroline Islands, Celebes, Cook Islands, Dutch Borneo, Dutch East Indies, Dutch New Guinea, Fiji, Guam, Hawaii, Java, Krakatau, Lord Howe Island, Mangareva Islands, Marshall Islands, New Caledonia, New Guinea, New Hebrides, New Zealand, Norfolk Island, North Borneo, Papua, Philippine Islands, Pitcairn Island, Samoa, Sarawak, South Borneo, Sumatra, Tahiti, Sunday Island, Tasmania, Tonga.

Collectors of *S. commune* report that natives in the following scattered areas consider the fungus edible: Belgian Congo, Peru, Assam, and Thailand. Notes accompanying specimens do not indicate how the fungus is eaten, whether raw or cooked. In Guatemala the fungus is known as "virinche"; the natives on Yap in the Caroline Islands call it "parefi," while those on Truk in the same group call it "soningan soome"; in the Belgian Congo the natives of Eala, Rungu-Wamba, and Immu call it "tukunw" or "buangi."

Schizophyllum radiatum (Swartz) Fr. and *S. brevilamellatum* Linder were both considered good species by Linder (1933). In his key, Linder separated *S. commune* and *S. radiatum* on the basis of spore size, the former having slightly longer and narrower spores than the latter. On the basis of a larger number of specimens and the total set of characters observed, these two species cannot be separated. Linder's geographic range for the two species places *S. commune* in the temperate regions with rare tropical records, whereas *S. radiatum* is restricted to the tropics. Collections have been seen in which both types of fruit bodies, entire to weak lobed contrasted with strongly flabelliform to digitate lobed, can

be observed in collections made from as far north as Minnesota and as far south as the Equator. On the basis of a large number of collections it is neither practical nor possible to separate species on the basis of spore size since there is a wide range of sizes within the limits of *S. commune* for length and *S. radiatum* for breadth within the materials now assigned to *S. commune*. *S. brevilamellatum* was based on a specimen with a very thick context and short lamelloid edges of contiguous receptacular walls. At least three specimens have been observed: the type from Venezuela, a specimen from Argentina, and a specimen from Kenya. The type of fruit body represented by this taxon was not represented among the fruiting types described by Raper and Krongelb (**1958**) and appears to be only an occasional habitat response of *S. commune*, which crops up at infrequent intervals at widely scattered locations.

The remaining taxa in the list of synonyms have been accepted as synonyms of *S. commune* since the publication of Linder's monograph or earlier.

TYPE specimens examined: *S. commune* f. *maxima* Rab., ad Salem, in Quercus trunco, leg. Jack. Rabenhorst, Fungi europaei, No. 705. (K, L). *S. commune* f. *lobatum* Sacc., on rotten logs, Padova, Italy, April. 1876. Collected by Saccardo. Saccardo, Mycotheca veneta No. 795. (K). *S. egelingianum* Ell. & Ev., collected by Egeling in Mexico. No location or date given. (NY). *S. brevilamellatum* Linder, Venezuela 1900, collected by Lt. M. Robinson. (FH).

In addition to the taxa listed in the synonymy, the following names have been assigned to specimens in herbaria. So far as the writer can ascertain, none of the following names have appeared in print. Some of these names have not been accredited to any specific author, nor have combinations, recombinations, and reassignment to subspecific category been credited. Usually it is not easy to decide who made the determination.

Schizophyllum commune var. *multifidum* (Batsch)—a name appearing on herbarium specimens from the Philippine Islands, Borneo, Brazil, Australia, and the Celebes.

S. commune forma *multifidum* Batsch—a name appearing on herbarium labels on specimens from the Philippine Islands and Australia.

S. commune var. *flabellare* (Fr.)—a name appearing on herbarium labels on specimens from Tahiti, British Guiana, and Georgia.

S. commune forma *flabellare* Fr., in herb., on wood, Belgian Congo. (BR).

S. commune forma *fuliginea* Bres., on *Ailanthus glandulosa,* Trident., Italy. (FH). Specimens with smoky surfaces were so labeled by Bresadola and deposited in the Patouillard Herbarium.

S. commune var. *laceratum* Pk., in herb., on *Fagus grandifolia,* Hudson Falls, New York, collected by S. H. Burnham, Oct. 20, 1905. (CUP).

S. commune forma *dictiflorum* Kellerman, in herb., on wood in the steam of hot springs, Zacapa, Guatemala. Collected by W. A. Kellerman 7662, Jan. 1, 1908. (NFC).

S. commune var. *orbicularis* Lév., in herb., *ad truncos,* Algerie. Collected by Bové. Determined and autographed by Léveillé. (PC).

S. commune var. *palmatum* Fr., in herb., on wood, Kuwantu, Belgian Congo, collected by J. Gillet, 1907. (BR).

S. commune var. *vetustum* Bres., in herb., on wood, Usambila, Belgian Congo, collected by R. P. Allan, Feb. 1910. (BR).

S. commune var. *minor* Junghuhn, in herb., probably on *Saccharum officinarum,* collected by Junghuhn near Buitenzorg, Java, Feb. (L).

Schizophyllum flabellare var. *pallidum* Mont., in herb. A specimen filed in a type cover at Kew bearing this name was collected in Guinea or Sierra Leone, Africa, and is labeled "ex herb. Montagne 2158." (K).

Schizophyllum multifidum Fr. A specimen from Fries in "Herb. Berkeley" is filed in a type folder numbered 2159 at Kew. A note on the folder states "true type is Batsch's El. Fung. f. 126."

Schizophyllum ramosum Schw. A specimen at the Farlow Herbarium from Surinam is filed under this name. No other data are given. (*ramiformis* Schw.).

Schizophyllum pusillum Fr., "nondum descriptum." A specimen so labeled filed in the Berkeley Herbarium at Kew was collected "Ad Cape York, Australia borealis," by Daenoch in 1862. It was identified by Wil. Hensche.

Agaricus crispatus sp. nov. A specimen so labeled, collected by H. C. Konig in Ceylon, is filed at Leiden. (L).

Agaricus alneus var. *subpetiolaris.* This name appears on the label of a specimen from Sarawak apparently obtained by Gaudichaud. (PC).

Lactea brunneola Rehm var. *brasiliensis* Bres. A specimen so labeled but without collection data is in the Theissen Herbarium. (FH).

It may be noted that the oldest name applied to a specimen of *S. commune* is: *Agaricus arborum villosum album inferiore temellatum.*

This appeared on a specimen without date or location information collected by H. C. v. Rooyen filed at Leiden. (L).

Lloyd is credited with the publication of the name *S. vulgare*. Since this name appears in a report of collections made in one of Lloyd's characteristic letters, it is suggested that the name was an error for *S. commune* since many other Lloyd collections are correctly labeled. The name was published without a diagnosis, however, and thus is a *nomen nudum*.

A comment may be made in connection with collecting activities of different people and people of different types of professions. Best host references were made by plant pathologists. "Mycologists" as differentiated from "plant" or "forest pathologists" gave the poorest data concerning host and habitat of the specimens they collected. The collection itself, the geographic distribution of a species based on these collections, and the host ranges listed in this report are therefore reflections of the interests of the individuals who made the collections.

Both from the point of view of host distribution and number of collections, the Philippine Islands are best represented. *S. commune* is represented by over 211 collections from at least 47 host species of woody plants. This is largely the result of the activities and interests of one pathologist, who instilled in his students some of his enthusiasm for the study of plant pathology in the field. This was Otto A. Reinking.

While the fungus may not be a true parasite but only a wound parasite or even only a saprobe, the host with which *S. commune* is associated most commonly is *Pyrus malus*, the apple. It has been found fruiting both on the wood of all parts of the tree and on the fruits themselves. Throughout the tropical world, wherever sugar cane is grown, *S. commune* is found on *Saccharum officinarum*. While fruits are found on internodes, the favored fruiting areas apparently are at the nodes on the culms of the cane.

The most unusual habitats for *S. commune* are in its association with man as a disease producing organism. It has been isolated once from toe nails of a patient in Philadelphia. Here fruiting was induced by growing the culture on compost. More recently in Brazil the fungus has been found in sputum, not unusual if the patient had been chewing the fungus fruits as is done in some regions, but most unusual since there appears to be pathological involvement (Ciferri, et al., **1956**). In a letter to J. A. Stevenson, Dr. Albert M. Kligman in connection with the case of onychomycosis said in part: "This fungus was isolated from a human toe-nail in which situation it had caused considerable difficulty."

The following paragraph may amplify the statements presented above concerning the practical importance of *Schizophyllum*. It is taken from

Singer (**1949**) and adds information not otherwise presented. "*Schizophyllum* often damages agricultural crops, usually under circumstances otherwise unfavorable for the host plant. Truck, berries, etc. are attacked; fruit trees also are attacked, mainly in wounds, and often perhaps as secondary infection. The author has observed *Schizophyllum radiatum* on recently harvested oranges in Florida, and *S. commune* on rhizomes of strawberries in Europe. Besides, all species of *Schizophyllum* are known to be rather active destroyers of wooden structures (railroad ties, telephone poles, etc.). The islanders in the Dutch East Indies and in Madagascar habitually chew carpophores of *Schizophyllum*."

S. commune is one of several fungi which cause considerable damage to such materials as balsa wood (*Ochroma lagopus*) used in such structures as light weight life rafts. A. S. Rhoads (**1948**) successfully developed a technique for preserving balsa wood used in this way. So far as the writer knows, this is the only attempt to control the growth of *S. commune* which has been published. The fungus is usually found as a producer of white rot in hardwoods, especially in slash.

SCHIZOPHYLLUM FASCIATUM Pat., Jour. Bot. **1**: 170. 1887.
Schizophyllum mexicanum Pat., Jour. Bot. **1**: 171. 1887.
Schizophyllum mexicanum var. *incisum* Pat., Bull. Soc. Mycol. Fr. No. 38. 1888.

Pileus reaching 3 cm deep and 5–6 cm wide, solitary to slightly imbricate, sessile or with a short stipe-like base, thin, coriaceous, reniform, entire to digitately lobed; surface densely villose, radiately sulcate near the margin, concentrically zonate with alternate light and dark zones, "pallid neutral gray" to light or deep "benzo brown," after preservation appearing chocolate to purplish brown. Context dense, 200–600 μ thick, hyaline, bordered on the periphery by a narrow subfuscous zone.

Hymenophore at first a disc with a smooth hymenium, becoming split radially, forming hymenophoral branches which develop hymenophoral units; more than 8 units in each hymenophoral branch at the base, 2–4–8 units in each branch in center of pileus, 2–4 units in each branch near the margin. Adjacent hymenophoral units appearing as split "lamellae" reaching one mm or more in length, "light drab," "pallid neutral gray" to deep "benzo brown," free surfaces covered with abhymenial hairs.

Abhymenial hairs brown, 2.5–4.5 μ in diameter, to 50–75 μ long, at first simple, soon becoming knobbed to geniculate, and finally irregularly short branched, forming a trichoderm. Surface hyphae brown, 3–4.5 μ in diameter, matted, forming tooth-like fascicles, forming a layer 200–600 μ thick. Context hyphae 2.5–3.5 μ in diameter, hyaline to pale

colored, giving rise to the subhymenium; no clamps observed; no gelatinous hyphae seen. Subhymenium 10 μ thick, composed of densely interwoven hyphae 1.5–2 μ in diameter.

Hymenium mostly 25 μ thick, composed of basidia and cystidia. Cystidia awl-shaped to subulate, hyaline or very dilutely colored, yellow in mass, few to usually many, projecting beyond the basidia up to half their length, 3.5–4.5 μ, reaching 5.5–7 μ in diameter, 20–23 μ or reaching 36–45 μ in length. Basidia clavate to broadly clavate, 13–20 $\times$ 4–6 μ, 4-sterigmate, sterigmata 2.5 μ long; no clamps observed.

Spores (5.5–)6.5–7 $\times$ 2–2.5 μ, hyaline under the microscope, smooth, apiculate, cylindric or elongate-ellipsoid.

Habitat: On dead wood and on the following identified substrata: thorny branch used as a fence, sugar cane, palmade, give-and-take palm, and *Dichrostachys nutans*.

Specimens examined: Mexico, Venezuela, Cuba, Guatemala, Florida, Guadeloupe, British West Indies (New Providence, Tortola), St. Thomas, Nicaragua, Danish West Indies, Ile de France, Isle of Pines, Jamaica, Bahamas, Haiti.

The above description was drawn from Dr. Linder's description and from notes made by the writer. It will be noted that this species is found around the Caribbean Sea and the Gulf of Mexico. It has not yet been reported from outside these drainage basins.

TYPE specimens examined: *S. fasciatum* Pat., on wood, Vera Cruz, Mexico, Aug. 1864. Collected by Salle, deposited in the herbarium of Bresadola, FH. *S. fasciatum* Pat. var. *mexicanum* Pat., on wood, Cuxtla, Mexico, 1856. PC, FH. *S. mexicanum* Pat. var. *incisum* Pat., on wood, San Fernando de Atabapo, Upper Orinoco, Venezuela, collected by Gaillard, Sept. 2, 1887. (FH, K).

In addition to the names listed in the synonymy above, two names have been found applied to specimens of this species which apparently have never been published.

Schizophyllum pavonium Berk., in Herb., collected Aug. 1854, Vera Cruz, Mexico, on half-burned wood. (K, PC, NY). If data on the label are presented accurately it appears that Berkeley had material of this species from the type locality 33 years before Patouillard published its description.

Schizophyllum fasciatum var. *mexicanum* Pat., in Herb. "Sur le bois pourri." Cuxtla, Mexico, 1856. (FH). Apparently Patouillard at first thought of this species as a variety of *S. fasciatum*, but later decided to give it specific status. That part of the specimen at Paris (PC) is labeled *S. mexicanum* Pat.

Killermann's citation (**1928**) of this species being represented by specimens from Guinea and Natal in Africa is erroneous unless it was based on specimens no longer available at Berlin (B). Such records were not found among specimens loaned by Stockholm (S) where a number of Sydow collections are still available.

A number of viable receptacles from a single collection site in Mexico (P. A. Lemke—Tulane 59174—Mts. west of Hy. 85, 28 M south of Monterey Bridge, 2500 ft., Nuevo Leon Prov., Sept. 13, 1959) were available to Raper for cultural and genetic studies. The species was found to be tetrapolar, with multiple factors in each incompatibility factor series, *A* and *B*, but even with biochemical mutations it could not be forced to interact with *S. commune* (Raper, **1960**).

SCHIZOPHYLLUM UMBRINUM Berk., Hook. Jour. Bot. **3**: 15. 1851.
Schizophyllum multifidum var. *digitatum* Ell. & Macbr., Univ. Iowa Bull. **3**: 194. 1896.

Pileus reaching 0.5–1.0 cm deep and 1–1.5 cm wide, rather thick, usually solitary, sometimes gregarious, sessile or subsessile to laterally or eccentrically stipitate and then pendant, the stipe-like base usually white strigose, the point of insertion on the substratum always with an encircling halo of white web-like hyphae radiating from the base of the pileus; bright golden brown when fresh, fading to brown or blackish, some old specimens weathering whitish. Surface scurfy to velutinous or appressed cottony, hyphae yellow to brown, loosely intertwined, forming a trichoderm. Context 300–550 μ thick, hyaline to tinged brownish, with a light brown surface zone.

Hymenophore initially a small disc, soon dividing into hymenophoral branches which produce up to 8 or more units, marginally each branch contains 2–4 units; context of hymenophoral branches 140–180 μ thick, 60–75 μ thick in hymenophoral units near margin; branches and units tightly inrolled when dry; opening when moistened to appear like split "lamellae" where they adjoin.

Surface hyphae yellow to brown, loosely intertwined, 2.5–4 μ in diameter, reaching 100 μ or more in length. Abhymenial hairs fuscous, closely applied, undulate or spirally undulate to somewhat contorted, 3.5–5 μ in diameter, forming a trichoderm on surfaces of hymenophoral units and branches. Context hyphae thick-walled, with a narrow lumen, 3.5–6 μ in diameter, when moistened appearing gelatinously thickened; subhymenial hyphae similar to context hyphae but narrower, 2–3.5 μ in diameter. No clamp connections observed.

Hymenium up to 25 μ thick. Basidia 13.5–23.5 $\times$ 4–5 μ, reaching 19–26 $\times$ 4–5 μ at maturity, 4-sterigmate, broadly clavate, tapering slightly toward the base, elongating beyond the hymenium at maturity,

at first with thick yellowish walls, then thin-walled, finally collapsing. No basal clamp connections observed. No cystidia found.

Spores hyaline under the microscope, 4.5–6 × 2–2.5 μ, smooth ellipsoid to short cylindric, apiculate.

Habitat: On dead wood including branches, decorticated hardwood saplings, and wood of such plants as *Bambusa* sp., *Bursera simaruba, Coccoloba diversifolia, Hevea brasiliensis, Mangifera indica, Metopium toxiferum, Persea americana, ?Rhus toxicodendron,* and *Vitis rotundifolia.*

Specimens examined: Florida, Mexico, Salvador, Nicaragua, Guatemala, Panama, Venezuela, British Guiana, Surinam, Haiti, Cuba, Bahamas.

It will be noted that this species is restricted in distribution to those countries bordering the Gulf of Mexico and the Caribbean Sea. On a recent expedition to the Florida Keys, A. S. Rhoads found it alone in abundance and also in association on the same sticks with *S. commune,* on several Keys.

Monosporous mycelia fruit readily in culture; there is no evidence of mycelial interaction of any kind, and the septa lack clamp connections. The species is apparently homothallic (Raper, **1959**).

TYPE specimens examined: *S. umbrinum* Berk., Wright 64. Cuba (K). (A collection by Wright from Filantropia, Cuba, at FH is labeled "authentic.") *S. multifidum* var. *digitatum* Ell. & Macbr., Ometepe, Nicaragua, collected by C. L. Smith, Jan.–Feb. 1893. (WIS, FH).

In addition to the names listed above, the name *Lentinus resupinus* Schw. appears on a specimen on bamboo collected in Surinam, and portions from the Schweinitz Herbarium are filed in the Farlow Herbarium (Curtis Collection) and at Kew (FH, K).

Schizophyllum palmatum Junghuhn, in Herb., Leiden.

Solitarium vel gregarium, pileis 0.5–1.0 × 1.0–1.5 cm, albis, sessilibus vel subsessilibus, flabelliformibus, margine e lobato ad palmatum, albopiloso trichodermate; carne 300–500 μ crassitudine, coriacea; pseudolamellis albis; basidiis 8–12 × 2.5–3.0 μ, clavatis, 4 sterigmatis instructis; sporis 3.2–4.0 × 1.5–2.0 μ, hyalinis, laevibus, apiculatis, ellipsoideis.

Pilei reaching 0.5–1.0 cm deep, and 1.0–1.5 cm wide, rather thick, solitary, white or ashen in dry specimens examined; sessile or subsessile to laterally substipitate, pendant, the stipe-like base with a halo of white web-like hyphae radiating onto the substratum from the base of the pileus; suborbicular to flabelliform with a lobate to deeply palmately cleft margin; surface covered with a 100 μ-deep villose trichoderm; context 300–500 μ thick, in older areas, thinner toward the margin, hyaline.

Hymenophore at first a small disc with a smooth hymenium, soon becoming split into hymenophoral branches dividing dichotomously into 4–8 hymenophoral units at the base, usually with 2 units per branch at the margin; branches becoming separate midway between the base and the margin; margins of branches and units tightly inrolled when dry; free surfaces of hymenophoral branches and units covered with a trichoderm composed of abhymenial hairs.

Abhymenial hairs subhyaline, projecting to 20 μ long, becoming capitate, terminal area of mature hair 4.5–6.5 μ in diameter, capped with a mass of crystals, 3–4 μ in diameter at the base; hyphae of the surface trichoderm 3–4.5 μ in diameter, reaching 100 μ or more in length, hyaline. Context hyphae 3–4 μ in diameter, hyaline to subhyaline, giving rise to the stereoid subhymenial hyphae; subhymenial hyphae 2–3 μ in diameter, hyaline, 2–3 μ in diameter, with clamp connections.

Hymenium reaching 15 μ in depth, composed only of basidia. Basidia 8–12 × 2.5–3.0 μ, 4-sterigmate, with clamp connections at the base. Sterigmata reaching 2 μ long.

Spores 3.2–4.0 × 1.5–2.0 μ, hyaline under the microscope, smooth, apiculate, ellipsoid. Not examined in Melzer's reagent or $FeSO_4$.

Habitat: On bark.

TYPE: Japan. Herb. V. Siebold. Labeled in Junghuhn's hand writing. Deposited in the Rijksherbarium, Leiden. (L). HLB 910-239-766, L1901/54.

The size of the spores and the shape of the abhymenial hairs keep this species distinct from the nearest appearing species, *S. umbrinum*. The geographic separation of the two species appears to warrant the recognition of this species even though it is based on only one collection, probably made more than 100 years ago. A note on the label following the indication of a name: "S. palmatum n. sp.," "insigne pileo palmato digitata," indicates that the specimen appeared distinct enough to Junghuhn to warrant establishment of a name for it.

Fresh material not having been available, cultural and genetic studies have not been made on this species.

Schizophyllum brasiliense W. B. Cooke, sp. nov.

Solitarium vel gregarium, pileis 0.5–1.5 × 1.0–1.5 cm, brunneis, subsessilibus, substipitatis lateraliter, flabelliformibus, margine ad lobatum, brunneopiloso, trichodermate; carne 1–1.5 mm crassitudine, coriacea, brunnea; pseudolamellis brunneis; basidiis 25–30 × 6–7 μ, clavatis, 4 sterigmatis instructis; sporis 9–11 × 2–2.5 μ, hyalinis, laevibus, apiculatis, cylindraceis.

Pilei small, 0.5–1.0 cm deep, 1.0–1.5 cm wide, solitarily to weakly imbricate, substipitate; suborbicular to flabelliform, with a weakly to strongly lobate margin, dark brown; covered by an appressed, woolly

trichoderm, dark brown, 150–175 μ thick. Context 1.0–1.5 mm thick at the center, appearing in two layers, the older portion brown, the younger hyaline, becoming thinner toward the margin.

Hymenophore at first a disc with a smooth hymenium, soon becoming divided into hymenophoral branches which divide dichotomously into 2–4 hymenophoral units; adjacent surfaces of hymenophoral branches or units fused to about one-half or two-thirds the depth of the pileus, then free; margins tightly inrolled when dry. Context of free portions of hymenophoral branches and units 75–100 μ thick, covered with a trichoderm formed of abhymenial hairs.

Hairs of surface trichoderm 3.5–5.0 μ in diameter, dark brown, free or interwoven, loose or compact. Abhymenial hairs in older areas 200–500 × 3.5–5.0 μ, dark brown, minutely granule-incrusted on outer two thirds of length, hyaline when young and then 2.0–2.5 μ in diameter, branched at the tip. Context hyphae 3.5–5.0 μ in diameter, hyaline to pale brown, with narrow lumen and thick walls, not gelatinous, giving rise to the stereoid subhymenium. Subhymenial hyphae 2.5–3.5 μ in diameter, compactly arranged.

Hymenium 25–30 μ thick, formed only of basidia; basidia 25–30 × 6–7 μ, 4-sterigmate, clavate; no cystidia found; no clamp connections seen. Sterigmata 1.5–3.0 μ long.

Spores 9–11 × 2–2.5 μ, hyaline under the microscope, smooth, apiculate, cylindric. Not examined in Melzer's reagent or $FeSO_4$.

Habitat: On old palm leaf and wood.

TYPE: Brazil, Goias. 143.5 km south of Peixe. Collected by E. Yale Dawson 15195, June 2, 1956. (SUI).

Other specimens examined: Brazil: Matto Grosso: Cerra de Chapada, March 5, 1894. Collected by G. Malme 560 (S). One of the two parts of this collection at Stockholm was tentatively identified as *S. exiguum* Miq.

This species is easily separated from the other species in this genus by the larger cylindric spores. Geographically, it is characterized by its occurrence, so far as is known to date, in central Brazil. A specimen sent by Martin to Raper as *S. umbrinum* was viable, and the resulting monosporous cultures failed to interact with each other and proved to be infertile with *S. commune*.

PHAEOSCHIZOPHYLLUM W. B. Cooke, gen. nov.

Simile *Schizophyllo*, sed sporis coloratis.

Characters as in Schizophyllum, but spores colored yellow to light brown.

Type species: *Schizophyllum leprieuri* Linder.

Phaeoschizophyllum leprieuri (Linder) W. B. Cooke, comb. nov.
Schizophyllum leprieuri Linder, Am. Jour. Bot. **20**: 561. 1933.

Fruit bodies small, 0.5–1.5 cm deep, 1.0–1.5 cm wide, solitary or slightly imbricate, subsessile or with a stipe-like base, suborbicular to flabelliform, dark brown, rather thick, coriaceous; margin weakly scalloped to lobate or digitate; surface covered with loosely interwoven hyphae forming a brown trichoderm 80–440 μ thick. Context brown, 240–400 μ thick.

Hymenophore at first a disc with a smooth hymenium, dividing soon into hymenophoral branches subdividing dichotomously into hymenophoral units, fused at points of initiation, 2, 4, 8, or 16 units per branch in older portions, 2, 4, or 8 in younger portions near margin, becoming free marginally, dark brown, short, tightly coiled when dry; adjacent margins forming "lamella-like" structures 280–440 μ long. Context of hymenophoral branches 160–215 μ thick at the base, 54–72 μ thick near the margin. Free surfaces of hymenophoral branches and units covered with a trichoderm formed of abhymenial hairs.

Abhymenial hairs light fuscous to brown, loosely interwoven, tortuous, irregular, appressed on older parts of surface, near margin somewhat branched, 90–100 μ long, 3–4 μ in diameter, outer two thirds of length granule-incrusted, branches subhyaline to hyaline, undulate, somewhat coiled or contorted, 1.8–2.7 μ in diameter. Context hyphae 3.5–5.5 μ in diameter, thick-walled, with a narrow lumen; when moistened, wall apparently gelatinously thickened; with clamp connections; giving rise to an indistinct to well-developed subhymenial area. Subhymenial hyphae 2.5–3 μ in diameter.

Hymenium 20–25 μ thick. Basidia 20–25(–36) × 4–5.5 μ, with basal clamp connections, at first clavate with thick lateral and terminal walls, finally clavate, less thick-walled, hyaline, 4-sterigmate; sterigmata 2.5 μ long; no cystidia observed.

Spores 5.6–7.5 × 2.5–4 μ, yellow brown to brown under the microscope, smooth, ovate to elongate ellipsoid, apiculate. Not examined in Melzer's reagent, Amann's solution or $FeSO_4$.

Habitat: On wood.

TYPE specimen: French Guiana: Collected by Leprieur No. 1003, in the herbarium of Richard, deposited in the Patouillard Herbarium (FH).

Other specimens examined: French Guiana: Collected by Leprieur No. 1001, in the herbarium of Richard, deposited in the Patouillard Herbarium (FH, PC). Colombia: Cerro Quemado above Hacienda Cincinnati, Magdalena, 2300 M. Aug. 24–26, 1935, GWM 3911 (SUI, FH); GWM 3312 (SUI) was collected at the same location, Aug. 9, 1935, at 1250–1500 M.

In the HOLOTYPE at the FH the hymenium appears somewhat hymenochaetoid. In Leprieur 1001, both at FH and PC, and in the specimens collected by Martin, the hymenium appears stereoid. The hymenochaetoid appearance may have been the result of unfavorable drying conditions after the type specimen had been soaked up for sectioning and study. This may also account for a lack of spores in the material examined by Linder since spores were quite evident in the PC portion of Leprieur 1001 and in the material of Martin at SUI. While Linder saw part of Leprieur 1001, it cannot be considered paratype material since it was not listed in his original description of this species.

The two groups of specimens known to date place this species on the northern coast of South America, within and near the Caribbean Sea drainage area, the area to which *S. umbrinum* and *S. fasciatum* are restricted.

Fresh material has not been available to John R. Raper, therefore, genetic studies of this species have not yet been made.

SPECIES NOT AVAILABLE FOR STUDY

Schizophyllum variabile Sorokin, Rev. Mycol. **1890**: 10, T. 38, f. 405–6. 1890.

From illustrations mounted on a herbarium sheet (NY), this species differs from *S. commune* only in the abhymenial hairs, a character which may not be of importance in this instance because of its variability throughout the collections observed.

Schizophyllum lobatum Brefeld

This name was found among those listed by Killermann (**1928**) in his treatment of the Basidiomycetes in Engler and Prantl. It was cited as having been collected on sugar cane in Java, and it was stated that Went had indicated that it produced CS_2. It is possible that this is the species cited in the synonymy above as *S. lobatum* Went.

GEOGRAPHIC DISTRIBUTION

Based on 3,714 specimens reported in TABLE I, by far the commonest species of *Schizophyllum* is the well named *S. commune*. More than 96% of these specimens have been assigned to this species. In contrast, only about 2% of the specimens were assigned to *S. umbrinum* and the same percentage to *S. fasciatum*. *S. leprieuri* is represented by only four collections, *S. brasiliense* by two, and *S. palmatum* by a single collection.

Specimens of *S. commune* have been reported from more than 300 named plant hosts in almost every political subdivision of every geographic area in the world. On the other hand, *S. fasciatum* and *S. umbrinum* have a more restricted distribution, having been collected only in countries and on islands surrounding the Caribbean Sea and the lower part of the Gulf of Mexico. *S. leprieuri,* the only species with colored spores, has been found only on the north coast of South America, two collections coming from the Caribbean Sea area and the other from land facing the Atlantic Ocean. *S. brasiliense,* the species with the largest spores, has been found only in Central and Western Brazil in central South America. *S. palmatum,* the species with the smallest spores, has been found only in Japan.

Within the time that John Raper has been studying the genetics of *Schizophyllum,* fresh material of *S. leprieuri* and *S. palmatum* has not been made available. Cultures of the other four species have been made from fresh material. None of these species have proved to be interfertile with another, and when specimens of two species occur on the same branch of a host plant, there has been no evidence of hybridization through appearance of the fruit bodies or cultures from spores produced by such fruit bodies. It appears that no matter where species in this genus originated or how long ago, they are at present so isolated genetically that hybridization cannot occur. It will be interesting to test this hypothesis with fresh material of *S. mexicanum,* now assigned as a synonym to *S. fasciatum.* This taxon is based on material similar in most respects to *S. fasciatum,* but with some characteristics of *S. commune.*

ILLUSTRATIONS

The best illustrations of the species of *Schizophyllum* are those of Linder (**1933**). The reader is referred to the four plates in that paper for detailed drawings of spores, basidia, hyphal types, abhymenial hairs, and structure of margins of the receptacular arms. Fig. 3 of Plate 34 shows one 4-unit receptacular arm with a portion of one unit of an adjacent arm. Figs. 1 and 2 of this plate show portions of a receptacular arm, as do Figs. 4, 5, and 6. Figs. 1, 3, and 6 of Plate 34 represent different habitat phases of *S. commune* in the sense of the present monograph.

Essig's paper (**1922**) presents illustrations of the developmental pattern of the sporophore according to his interpretation. Ehrlich and McDonough (**1949**) illustrate the nuclear history of the basidium and basidiospores.

Martin (**1941**) illustrates the abhymenial hairs, young basidia, and spores of *S. leprieuri*.

The different types of fruiting observed in culture and by Raper and his students are well illustrated by Raper and Krongelb (**1958**) in their Figs. 3–11.

Because of the wealth of illustrative material listed above and that found in other cited papers, as well as that which appears throughout the literature of agaricology and mycophagy, it is believed that presentation of additional illustrative material would be superfluous.

ACKNOWLEDGMENTS

The writer wishes to take this opportunity to thank all those who have contributed to the completion of this study. The continued encouragement of John R. Raper throughout the course of the study has been most helpful. Through his efforts fresh material of *S. umbrinum* became available as a result of an expedition to the Florida Keys by Dr. A. S. Rhoads. His extensive collection of *S. commune* fruit bodies and cultures confirmed the diagnosis that *S. radiatum* and *S. commune* are merely habitat manifestations of one species. The curators of the herbaria listed in TABLE I are to be thanked for permitting examination of prized herbarium material in a laboratory far from home. Helpful suggestions have been given by G. W. Martin, A. H. Smith, and J. A. Stevenson, who read the manuscript. Valuable library help has been given by the staff of the Lloyd library.

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A NEW SPECIES OF ELSINOË ON PANICUM VIRGATUM [1]

LOIS H. TIFFANY AND JUDITH H. MATHRE [2]

(WITH 5 FIGURES)

One of the common leaf-spotting pathogens observed in the course of a several year survey of the fungi occurring on grasses in Iowa has been found to be an undescribed species of *Elsinoë* on *Panicum virgatum* L. The first collections were made by the senior author near Ames in September, 1957. Since that time the fungus has been collected in four counties in central Iowa. At two of these locations, Kalsow Prairie in Pocahontas County and a roadside area north of Ames in Story County, collections have been made regularly in the past three years. The fungus seems to be rather widely distributed throughout Iowa, and possibly could be present on *Panicum virgatum* throughout its entire range.

Upon examination of the *Panicum virgatum* specimens in the Iowa State University herbarium, a collection was found of a leaf spot on this host made by C. E. Bessey on October 20, 1882. The specimen originally labeled as *Dothidea graminis* Fr. was examined by C. R. Orton on March 29, 1918 in the course of his studies with *Phyllachora* and annotated as follows: "Probably not *Phyllachora*. The fungus has only a few conidia; no asci or ascospores. Cannot determine in present condition. Should like to know if it can be found again, it's a new one to me."

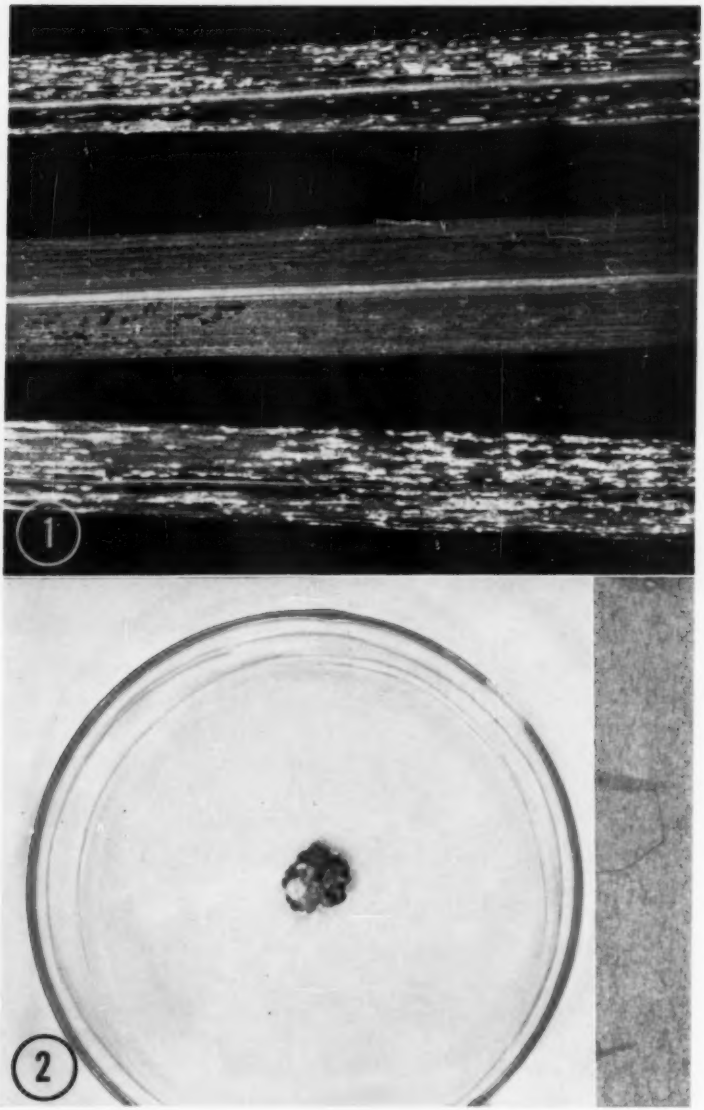
Specimens collected by the authors in late September and October have also been almost devoid of spores, and are identical in appearance with the early Bessey collection.

An intensive search of the literature concerned with the Myriangiales, indicated that the only reports of a member of this group of fungi on one of the Gramineae are those of *Myriangium bambusae* Rick (**1**, **2**) on cultivated bamboo, originally described in Brazil.[3] This paper therefore, is a brief initial report of the *Panicum* pathogen.

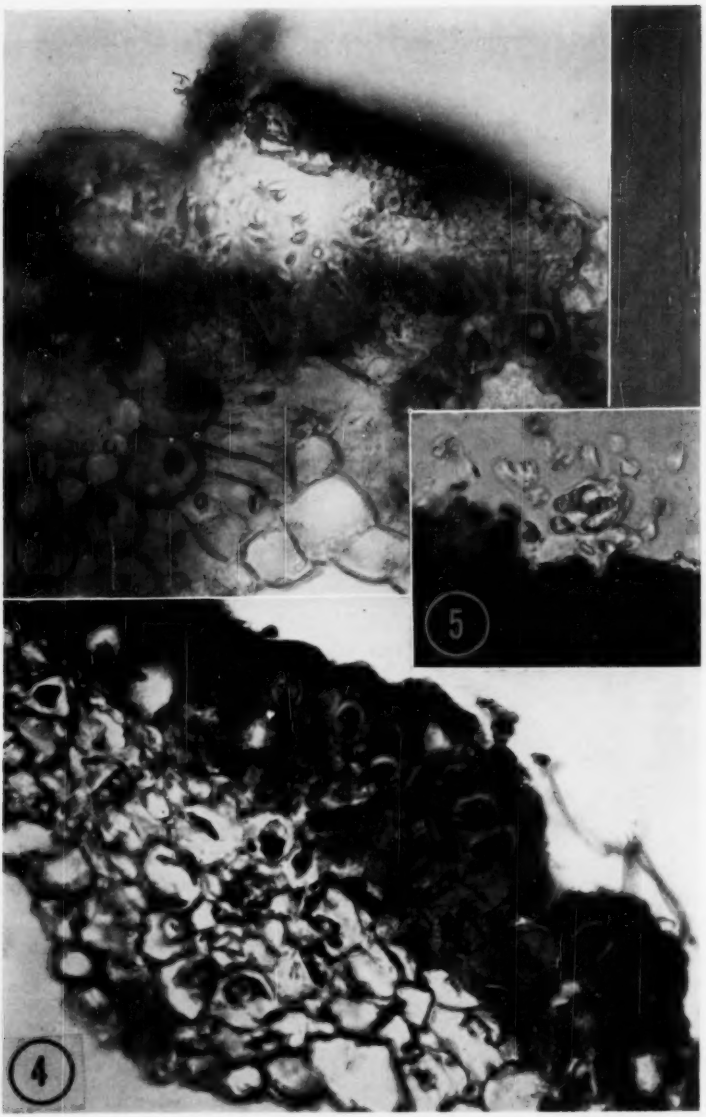
[1] Journal Paper No. J-4256 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1333.

[2] The authors are indebted to Dr. J. C. Gilman for his interest in this investigation and his preparation of the Latin diagnosis.

[3] Since submission of this paper to Mycologia, the report of an unnamed species of *Elsinoë* on sugarcane (Todd, E. H. 1960. *Elsinoë* disease of sugarcane in Florida. Pl. Dis. Reporter **44**: 153) has been noted.



FIGS. 1, 2. *Elsinoë panici.* 1. On leaves of *Panicum virgatum.* 2. Culture.



FIGS. 3–5. *Elsinoë panici*. 3. Free-hand cross section of *Panicum virgatum* leaf through conidial area of a young stroma. × 400. 4. Microtome cross section of mature stromata in a *Panicum virgatum* leaf. × 400. 5. Ascus with outer wall broken, inner wall just beginning to expand. × 400.

The fungus is found most commonly on the leaves, causing leaf spots that are oval to oblong, white to cream colored pustules in which the conidial (*Sphaceloma*) stage develops. With age black stroma grows around the area of the original pustule, resulting in elongate lesions 10 to 20 mm in length that frequently coalesce with adjacent stromata (FIG. 1). The pustular light colored central area remains, creating an eyespot type of lesion. Similar scab-like pustules develop on leaf sheaths, culms and panicles.

The conidia of the *Sphaceloma* stage were produced on a poorly defined, densely packed layer of conidiophores formed in or under the epidermal cells and exposed as the epidermal layer was irregularly ruptured by the development of the spores (FIG. 3). Hyaline, oblong conidia, 5.5–7.5 × 2.5–3.7 μ were produced.

Study of freehand sections of fresh material and of stained microtome sections of preserved material indicated that globose double-walled asci arose at various levels in the stroma (FIG. 4). They were 17.5–20 × 17.5–25 μ and contained eight ascospores. The spores were hyaline to lightly colored, initially with a single central septum but slowly becoming 3-septate and 10–15 × 2.5–5 μ (FIG. 5). The ascus-bearing stromata begin to form in the epidermal cells from closely packed mycelial strands. Gradually the host cells are completely disrupted by the mass of fungus hyphae, and the stromatic area is evident.

Cultures of the fungus were readily obtained from fresh field material during the summer of 1960. During the previous winter attempts to isolate the organism from dried material had been unsuccessful. The organism grew best on potato dextrose agar and high glucose yeast extract agar; however, even on these media the colonies seldom exceeded one inch in diameter (FIG. 2). Initially, colonies were pink in color, becoming black with age. Intensity of pigmentation varied on different media. On corn meal agar, low glucose yeast extract agar, low glucose agar made with an extract from leaves of *Panicum virgatum* or of *Bromus inermis* Leyss, poor growth was obtained. Slightly better growth resulted on sterile *Panicum virgatum* leaves on water agar.

On all media, the colonies were irregularly heaped to cushion shaped. They consisted of compact masses of interwoven hyphae, with conidia eventually produced irregularly on the older colonies.

Elsinoë panici Tiffany & Mathre, sp. nov.

Maculae epiphyllae, sparsae vel aggregatae et coalescentes, e linearibus ad angulares, ex albis ad griseas, brunneo-marginatae; stroma intra vel sub epidermide conidiophoris erumpentibus pallidis compactos acervulos fingentibus; conidia hyalina,

ovoidea vel oblongo-elliptica, 5.5–5.7 × 2.5–3.7 μ; ascocarpi subcuticulares vel intra epidermidem, erumpentes, applanati; asci numerosi in stratis (1–2) irregulariter dispersi, e globosis ad late ellipticos, bitunicati, sessiles, 17.5–20 × 17.5–25 μ; ascosporae irregulariter dispositae, clavato-ellipsoideae, 3-septatae, e hyalinis ad pallidas, 10–15 × 2.5–5 μ.

Hab. in foliis *Panici virgati* L., Iowa.

Spots epiphyllous, visible on only one surface of the leaf, 10–20 mm in length, isolated to aggregated and coalescent, linear to somewhat irregular, with light pustulate areas in center. Conidiophores aggregated in center of young lesions, arising in or under the epidermis. Conidia hyaline, ovoid to oblong, 5.5–7.5 × 2.5–4.7 μ. Ascocarps subcuticular or intraepidermal in origin, upper surface becoming exposed, flattened, asci disposed singly in locules at irregular levels, in different stages of development, globose to broadly elliptical, bitunicate, sessile, 17.5–20 × 17.5–25 μ; ascospores irregularly arranged, oblong-ellipsoid, 3-septate with an occasional longitudinal wall, hyaline to pallid, 10–15 × 2.5–5 μ.

Distribution: On leaves, leaf sheaths, culms and panicles of *Panicum virgatum* L., Iowa, U.S.A.

TYPE: On *Panicum virgatum*, roadside three miles south of Ames, Story County, September 10, 1957, L. H. Tiffany, Iowa State University 230687.

Specimens examined: On *Panicum virgatum*, roadside west of Ames, Story Co., Sept. 10, 1957, L. H. Tiffany; Kalsow Prairie, Pocahontas Co., July 26, 1959, J. H. Mathre; Kalsow Prairie, July 26, 1959, L. H. Tiffany; Boone Co. road, Aug. 7, 1959, J. H. Mathre; Boone Co., Aug. 8, 1959, J. H. Mathre; Boone Co., July 13, 1960, J. H. Mathre; Kalsow Prairie, July 18, 1960, J. H. Mathre; Roland, Story Co., July 27, 1960, J. H. Mathre; Woodman Hollow State Park, Webster Co., July 31, 1960, K. Juhl; Boxholm, Boone Co., Aug. 5, 1960, J. H. Mathre; Ledges State Park, Boone Co., Aug. 9, 1960, J. H. Mathre; Story Co. Road, Aug. 16, 1960, J. H. Mathre: Roadside north of Ames, July 25, 1961, L. H. Tiffany and K. Juhl; Kalsow Prairie, Pocahontas Co., Aug. 11, 1961, L. H. Tiffany and K. Juhl; roadside, Boone Co., Sept. 22, 1961, L. H. Tiffany and K. Juhl.

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A STUDY OF RUSSULA TYPES, II [1]

L. R. HESLER

(WITH 136 FIGURES)

This paper is a second report of studies on North American types of *Russula* species. An earlier publication (Hesler, **1960**) treated one hundred fifty-nine types of species of this genus; in this account thirty-four additional North American types are reported. In each of these papers, attention has been given to the spores (size and ornamentation), to the pleurocystidia and cheilocystidia, and to the epicutis and its component elements. Drawings to represent the characteristics of these structures are presented for each species.

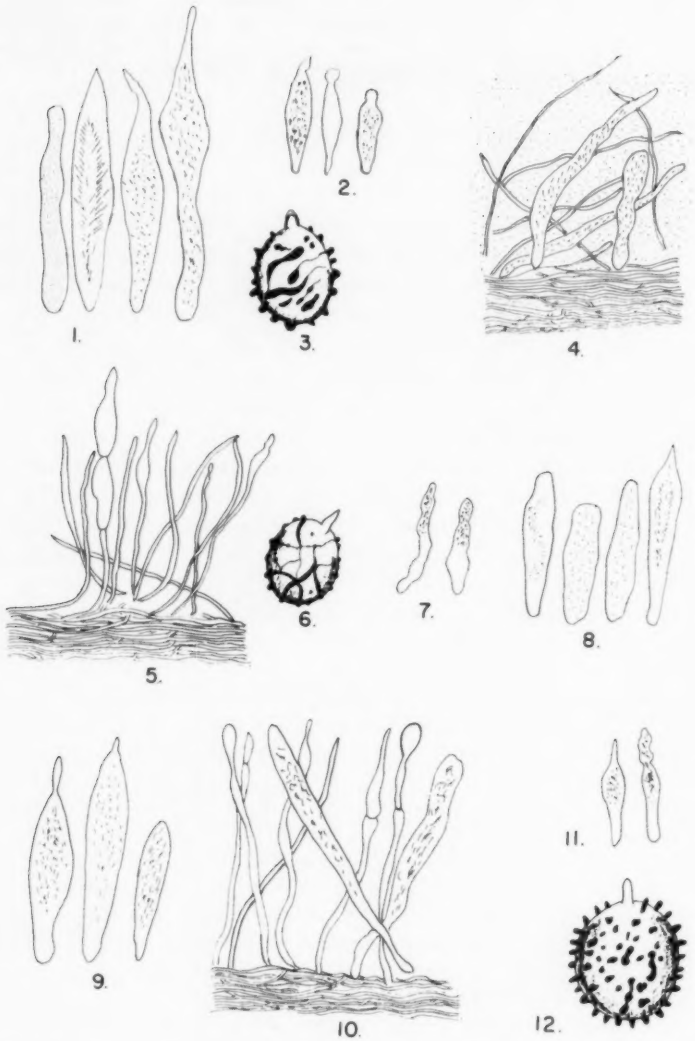
Acknowledgment is made to the National Science Foundation for a grant supporting these studies, and to The New York Botanical Garden Herbarium for a loan of types. The drawings, originally prepared by the author, were traced for publication by Mr. M. B. Yeligar, a graduate student in botany.

In the illustrations, the spores are figured at a magnification × 1500; and other structures × 500.

R. ALCALINICOLA Burl., Mycologia **16**: 18. 1924. *Spores* (FIG. 3) 8–10 × 7–8 μ, ellipsoid, warts blunt, 0.4–0.7 μ high, a few isolated, some catenulate, with a few fine lines more rarely forming an incomplete reticulum. *Pleurocystidia* (FIG. 1) 58–90 × 7–13 μ, conspicuous, fusoid, more rarely obclavate, apices acute, rarely blunt, at times appendiculate, granular or banded; *cheilocystidia* (FIG. 2) 24–32 × 6–7 μ, few, inconspicuous, fusoid or clavate, subcapitate, empty, granular, or banded. *Subhymenium* of small irregular cells. *Epicutis* (FIG. 4) of the *emetica*-type: a gelatinous zone (ixotrichodermium) about 30 μ broad, hyphae slender, more or less erect, with conspicuous, banded *pilocystidia*, 40–110 × 5–8 μ, apices acute or rounded. *Hypodermium* (FIG. 4) about 20 μ broad, of slender, parallel hyphae.

R. ASTRINGENS Burl., North American Flora **9**: 227. 1915. *Spores* (FIG. 6) 7–9 × 5.5–7 μ, ellipsoid, subovoid, more rarely subpyriform, warts mostly 0.1 μ or less, a few up to 0.4 μ high, with connecting bands and fine lines forming a partial or complete, often indistinct reticulum.

[1] Contributions from the Botanical Laboratory, The University of Tennessee, N. Ser. No. 232.



FIGS. 1–4: *Russula alcalinicola.* 1. Pleurocystidia. 2. Cheilocystidia. 3. Spore. 4. Epicutis. FIGS. 5–8: *Russula astringens.* 5. Epicutis. 6. Spore. 7. Cheilocystidia. 8. Pleurocystidia. FIGS. 9–12: *Russula betulina.* 9. Pleurocystidia. 10. Epicutis. 11. Cheilocystidia. 12. Spore.

Pleurocystidia (FIG. 8) 34–52 × 8–9 μ, buried and inconspicuous, fusoid to clavate, apices truncate, rounded, or occasionally appendiculate, granular or banded; *cheilocystidia* (FIG. 7) 25–33 × 4–6 μ, cylindric or bottle-shaped, few in number, granular. *Subhymenium* of small, flattened cells. *Epicutis* (FIG. 5) an ixotrichodermial palisade (a turf), hyphae slender, a few hyphae constricted, broad, and the terminal element cystidioid. *Hypodermium* (FIG. 5) conspicuous.

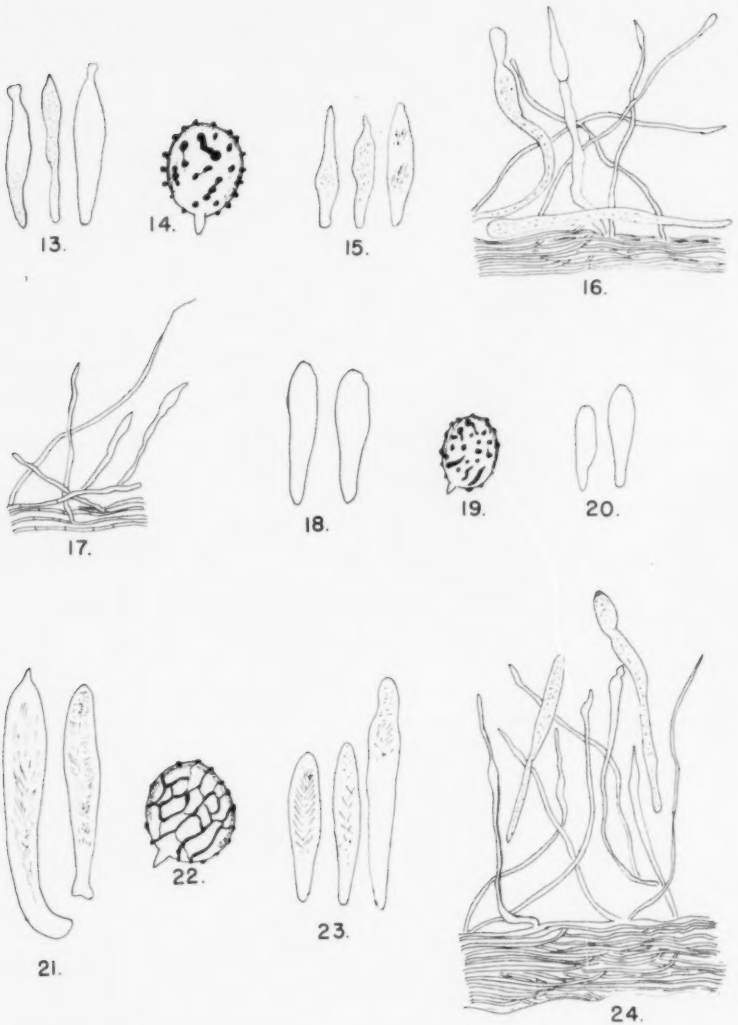
R. BETULINA Burl., North American Flora **9**: 227. 1915. *Spores* (FIG. 12) 9–12 × 8–10 μ, ellipsoid, with abundant spines, 0.7–1.2 μ high, isolated, a very few short-catenulate. *Pleurocystidia* (FIG. 9) 38–63 × 9–13 μ, clavate or fusoid, apices rounded or appendiculate, granular, or banded; *chleilocystidia* (FIG. 11) 30–33 × 4–7 μ, rare, clavate or cylindric, at times appendiculate, granular. *Subhymenium* of small, flat cells. *Epicutis* (FIG. 10) an ixotrichodermium of the *emetica*-type, hyphae forming a semi-palisade, the terminal elements acute or subcapitate, at times constricted. *Pilocystidia* and *hypodermium* (FIG. 10) conspicuous.

Singer (**1942**) has pointed out that the spores and dermatocystidia distinguish this species from *R. integra* (L.) Fr. sensu Singer (*R. velenovskyi* Melz. & Zvára).

R. BICOLOR Burl., Mycologia **5**: 311. 1913. *Spores* (FIG. 14) 8–9.5 × (5.5–)7–8 μ, ellipsoid, warts 0.3–0.4(–0.5) μ high, many isolated, some catenulate, few or no connecting fine lines. *Pleurocystidia* (FIG. 13) 40–45 × 5–10 μ, clavate, acute or appendiculate, granular, minutely banded, or empty; *cheilocystdia* (FIG. 15) few, 32–35 × 5–7 μ, flask-shaped or clavate, apices appendiculate or rounded, granular, or minutely banded. *Subhymenium* a narrow zone of small cells. *Epicutis* (FIG. 16) an ixotrichodermium, with a few, inconspicuous *pilocystidia*. *Hypodermium* present (FIG. 16).

R. BLANDA Burl., North American Flora **9**: 213. 1915. *Spores* (FIG. 19) 6–7.3 × 5–5.5 μ, ellipsoid or subovoid, warts very short, often as punctations, at times the wall nearly smooth, warts isolated, some more or less catenulate, no fine lines. *Pleurocystidia* (FIG. 18) 37–40 × 8–10 μ, clavate, few, empty; *cheilocystidia* (FIG. 20) 24–30 × 5–6 μ, clavate, few empty. *Subhymenium* of small cells. *Epicutis* (FIG. 17) a narrow, somewhat gelatinous zone of repent and more or less erect hyphae; the squamules are composed of tufts of hyphae. *Pilocystidia* none. *Hypodermium* poorly developed (FIG. 17).

Singer (**1942**) found the spores slightly larger and with longer ornamentations than reported above. He suggests that it needs further study and comparison with the European *R. lactea*, a species which Schaeffer (**1952**) thinks may be a form of *R. lepida* Fr.



FIGS. 13–16: *Russula bicolor*. 13. Pleurocystidia. 14. Spore. 15. Cheilocystidia. 16. Epicutis. FIGS. 17–20: *Russula blanda*. 17. Epicutis. 18. Pleurocystidia. 19. Spore. 20. Cheilocystidia. FIGS. 21–24: *Russula californiensis*. 21. Pleurocystidia. 22. Spore. 23. Cheilocystidia. 24. Epicutis.

R. CALIFORIENSIS Burl., Mycologia **28**: 262. 1936. *Spores* (FIG. 22) (7–)8–11 × (7–)8–9 μ, ellipsoid, warts punctate, 0.1 μ high or less, with connecting bands and lines forming a complete or rarely a partial reticulum. *Pleurocystidia* (FIG. 21) 62–77 × 10–13 μ, clavate, subacute or mucronate, banded; *cheilocystidia* (FIG. 23) 42–66 × 7–10 μ, clavate or subcylindric, granular or banded. *Subhymenium* of small cells. *Epicutis* (FIG. 24) a broad zone of gelatinous, more or less tangled to erect hyphae with scattered *pilocystidia*—of the *emetica*-type. *Hypodermium* conspicuous (FIG. 24).

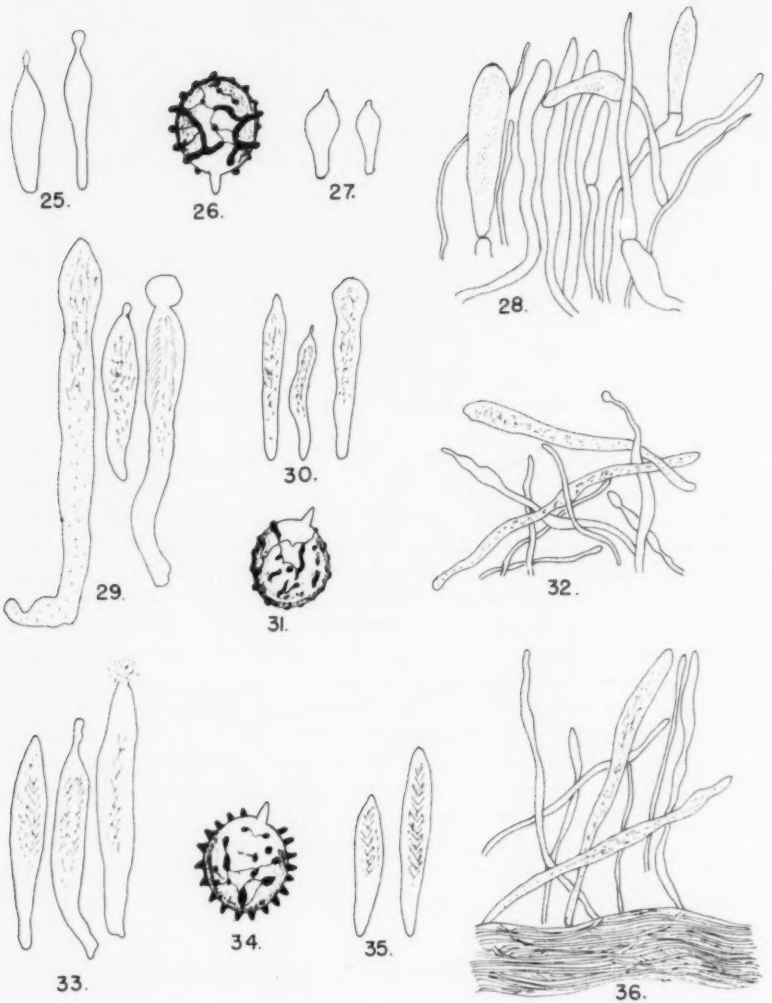
R. CORINTHIIRUBRA Burl., North American Flora **9**: 220. 1915. *Spores* (FIG. 26) 8–10 × 7–8 μ, ellipsoid, warts 0.4–0.8 μ, connected by bands and lines forming a reticulum. *Pleurocystidia* (FIG. 25) 36–47 × 8–10 μ, clavate, mucronate, empty; *cheilocystidia* (FIG. 27) few, 22–25 × 6–10 μ, subclavate to inverted-flask shaped, mucronate, empty. *Subhymenium* a narrow zone of small cells. *Epicutis* (FIG. 28) an ixotrichodermium, hyphae repent, erect, or semi-erect, with scattered, usually inconspicuous *pilocystidia*. *Hypodermium* absent or inconspicuous.

R. CREMORICOLOR Earle, Bulletin New York Botanical Garden **2**: 340. 1902. *Spores* (FIG. 31) (6.5–)8–9 × (5.5–)7–8 μ, ellipsoid to subglobose, warts 0.1–0.3 μ high, isolated or with a few fine lines, at times catenulate. *Pleurocystidia* (FIG. 29) 50–127 × 9–13 μ, more or less clavate or subcylindric, acute, obtuse, or capitate, granular or banded, many arising in the gill-trama; *cheilocystidia* (FIG. 30) 43–52 × 5–9 μ, clavate, more or less acute or mucronate, banded. *Subhymenium* a narrow zone of flattened cells. *Epicutis* (FIG. 32) a zone of gelatinous, more or less periclinally-arranged hyphae, the surface hyphae more or less erect, with *pilocystidia*. *Hypodermium* not distinct.

R. CRENULATA Burl., Mycologia **5**: 310. 1913. *Spores* (FIG. 34) 9–11 × 7–9.5 μ, ellipsoid to subglobose, warts 0.6–1.2 μ high, some catenulate, with few or many fine lines forming a more or less complete reticulum. *Pleurocystidia* (FIG. 33) 61–76 × 10–12 μ, fusoid, acute or appendiculate, at times with an apical exudate, banded; *cheilocystidia* (FIG. 35) fusoid, 40–54 × 7–8 μ, banded, acute. *Subhymenium* of small cells. *Epicutis* (FIG. 36) of the *emetica*-type; *pilocystidia* numerous.

The close relationship of this species to *R. emetica* ssp. *emeticella* is discussed by Singer (**1957**).

R. DAVISII Burl., Mycologia **10**: 93. 1918. *Spores* (FIG. 38) 9–13 × 8–9(–11) μ, ellipsoid, warts (0.5–)0.8–1.4 μ high, many isolated, some cantenulate, some with fine lines. *Pleurocystidia* (FIG. 37) 66–94 × 5–12 μ, numerous, conspicuous, variable in shape and diameter, cylindric, clavate, fusoid, irregular, at times constricted, acute or ap-



FIGS. 25–28: *Russula corinthiirubra.* 25. Pleurocystidia. 26. Spore. 27. Cheilocystidia. 28. Epicutis. FIGS. 29–32: *Russula cremoricolor.* 29. Pleurocystidia. 30. Cheilocystidia. 31. Spore. 32. Epicutis. FIGS. 33–36: *Russula crenulata.* 33. Pleurocystidia. 34. Spore. 35. Cheilocystidia. 36. Epicutis.

pendiculate, empty, granular, or banded; *cheilocystidia* (FIG. 39) 50–70 × 4–10 μ, similar. *Subhymenium* of small cells. *Epicutis* (FIG. 40) a trichodermium, often more or less a turf, with trichodermial tufts of hyphae at intervals. No *pilocystidia*, and no *hypodermium*.

Singer (**1942**) found the spores to be slightly larger than reported above. He suggests its close relationship to *R. olivacea*.

R. DISPARILIS Burl., Mycologia **10**: 94. 1918. *Spores* (FIG. 42) 7.5–9(–10) × 6–7.5(–9) μ, subglobose or ellipsoid, warts 0.3–0.5(–1.0) μ high, isolated or somewhat catenulate, rarely with a few inconspicuous fine lines. *Pleurocystidia* (FIG. 41) 40–68 × 7–10 μ, clavate to fusoid, apices acute or mucronate, empty, granular, or banded; *cheilocystidia* (FIG. 43) 30–50 × 4–5 μ, clavate, at times appendiculate, granular. *Subhymenium* of small cells. *Epicutis* (FIG. 44) a turf of gelatinous hyphae, with a few, inconspicuous, granular *pilocystidia*. *Hypodermium* present (FIG. 44).

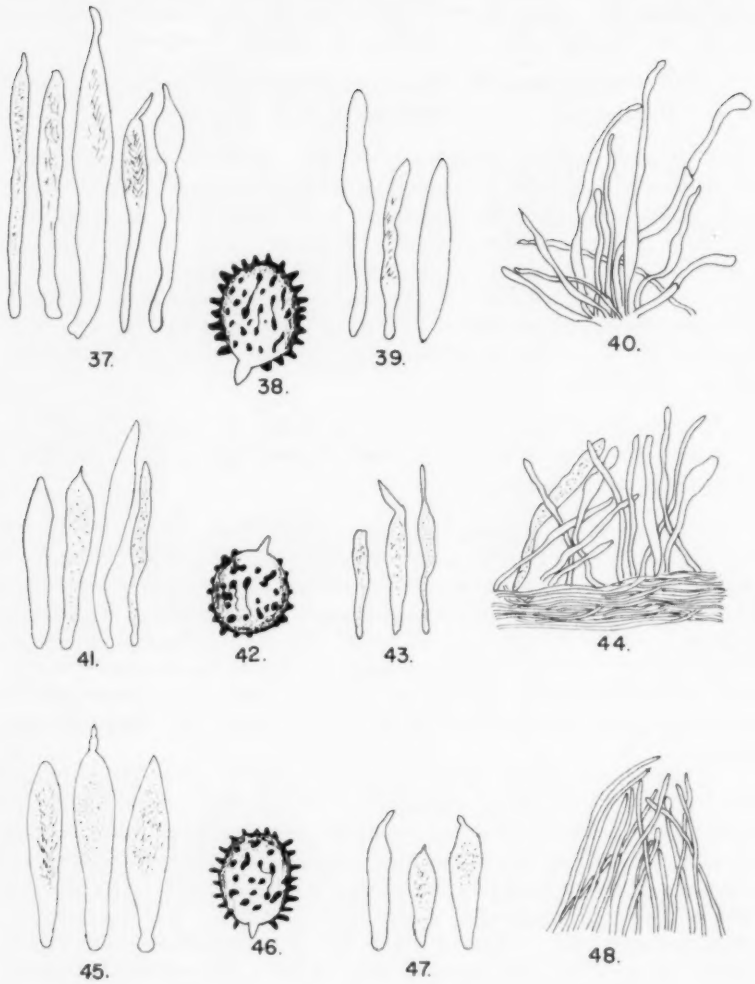
Singer (**1957**) regards *R. echinospora* Sing. as a synonym, and distinguishes *R. disparilis* from a similarly colored species, *R. fusca* Quél., in the spore ornamentation.

R. FUCOSA Burl., Mycologia **16**: 20. 1924. *Spores* (FIG. 46) 8–10.5 × 7–8.5 μ, ellipsoid, warts mostly slender, 0.7–1.3 μ high, isolated or slightly catenulate, with an occasional fine line. *Pleurocystidia* (FIG. 45) 55–63 × 11–13 μ, fusoid or clavate, acute or appendiculate, granular or mintely banded; *cheilocystidia* (FIG. 47) 28–40 × 6–8 μ, not abundant, clavate to subcylindric, empty or granular, apices mucronate. *Subhymenium* of small cells. *Epicutis* (FIG. 48) a turf of gelatinous hyphae, often aggregated into tufts, or mounds. No *pilocystidia*. *Hypodermium* indistinct.

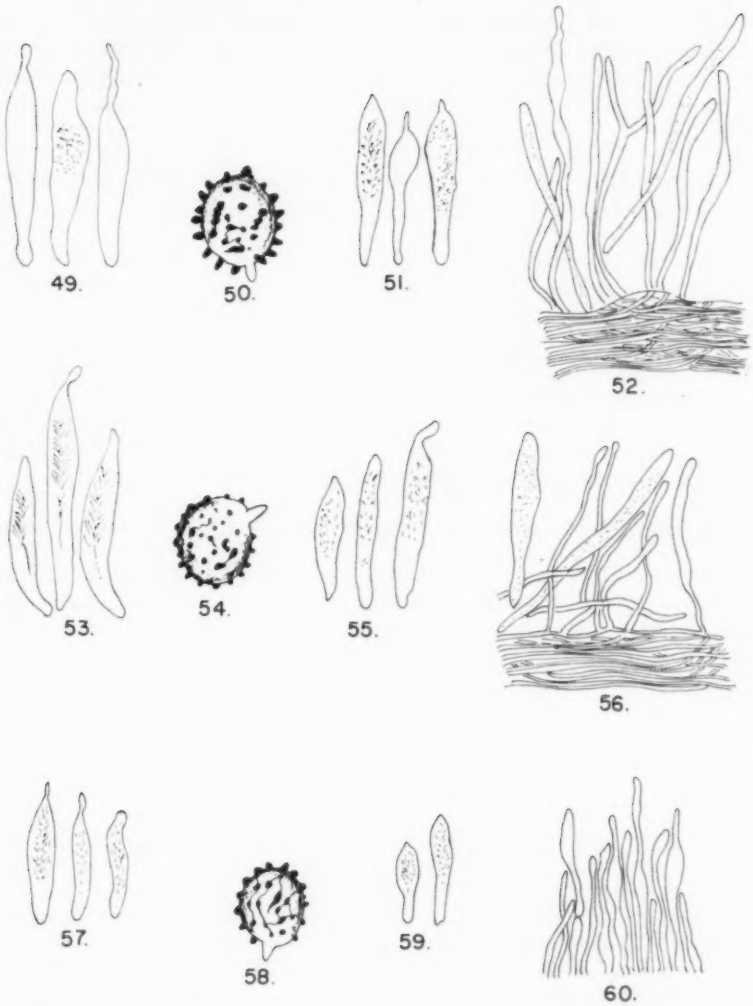
R. FULVESCENS Burl., North American Flora **9**: 229. 1915. *Spores* (FIG. 50) 9–11 × 7–8.5 μ, ellipsoid, warts 0.5–1.0 μ high, isolated or more or less catenulate, a few inconspicuous fine lines often present. *Pleurocystidia* (FIG. 49) 55–64 × 7–11 μ, clavate, acute or appendiculate, empty or granular; *cheilocystidia* (FIG. 51) 42–50 × 4–8 μ, clavate or subfusoid, empty, granular, or minutely banded. *Subhymenium* of small, compact cells. *Epicutis* (FIG. 52) of the *emetica*-type: a turf of gelatinous hyphae, with several *pilocystidia*. *Hypodermium* present (FIG. 52).

Singer (**1942**) found the spores of the type to be 8.5–12.8 × 7.3–10.2 μ.

R. GRACILIS Burl., North American Flora **9**: 222. 1915. *Spores* (FIG. 54) 7.5–9 × (5.5–)6–7 μ, ellipsoid, warts 0.3–0.5(–0.6) μ high,



FIGS. 37–40: *Russula davisii*. 37. Pleurocystidia. 38. Spore. 39. Cheilocystidia. 40. Epicutis. FIGS. 41–44: *Russula disparilis*. 41. Pleurocystidia. 42. Spore. 43. Cheilocystidia. 44. Epicutis. FIGS. 45–48: *Russula fucosa*. 45. Pleurocystidia. 46. Spore. 47. Cheilocystidia. 48. Epicutis.



FIGS. 49–52: *Russula fulvescens*. 49. Pleurocystidia. 50. Spore. 51. Cheilocystidia. 52. Epicutis. FIGS. 53–56: *Russula gracilis*. 53. Pleurocystidia. 54. Spore. 55. Cheilocystidia. 56. Epicutis. FIGS. 57–60: *Russula hibbardae*. 57. Pleurocystidia. 58. Spore. 59. Cheilocystidia. 60. Epicutis.

isolated, rarely short-catenulate, a few inconspicuous fine lines. *Pleurocystidia* (FIG. 53) 50–70 × 7–10 μ, fusoid or subclavate, acute or appendiculate, banded; *cheilocystidia* (FIG. 55) 36–48 × 6–8 μ, cylindric to subfusoid, acute, obtuse, or appendiculate, banded. *Subhymenium* of small cells. *Epicutis* (FIG. 56) of the *emetica*-type, hyphae, gelatinous, erect or semi-erect, with scattered *pilocystidia*. *Hypodermium* present (FIG. 56).

Singer (**1942**) reports the spores slightly larger than given above. He (**1957**) regards *R. gracillima* J. Schaeff. as a synonym.

R. HIBBARDAE Burl., Mycologia **13**: 132. 1921. *Spores* (FIG. 58) 7–8 × 6–7 μ, ellipsoid or subglobose, warts 0.4–0.6 μ high, some spores reticulate with fine lines, others with an incomplete reticulum, at times the warts isolated or catenulate. *Pleurocystidia* (FIG. 57) small, 30–40 × 5–7 μ, fusoid to irregular, very few and inconspicuous, acute or mucronate, banded: *cheilocystidia* (FIG. 59) small, 22–30 × 5–6 μ, rare, absent in many sections, more or less acute, banded. *Subhymenium* of small cells. *Epicutis* (FIG. 60) a turf of gelatinous, rather irregular hyphae, some hyphae more or less cystidioid. *Hypodermium* none.

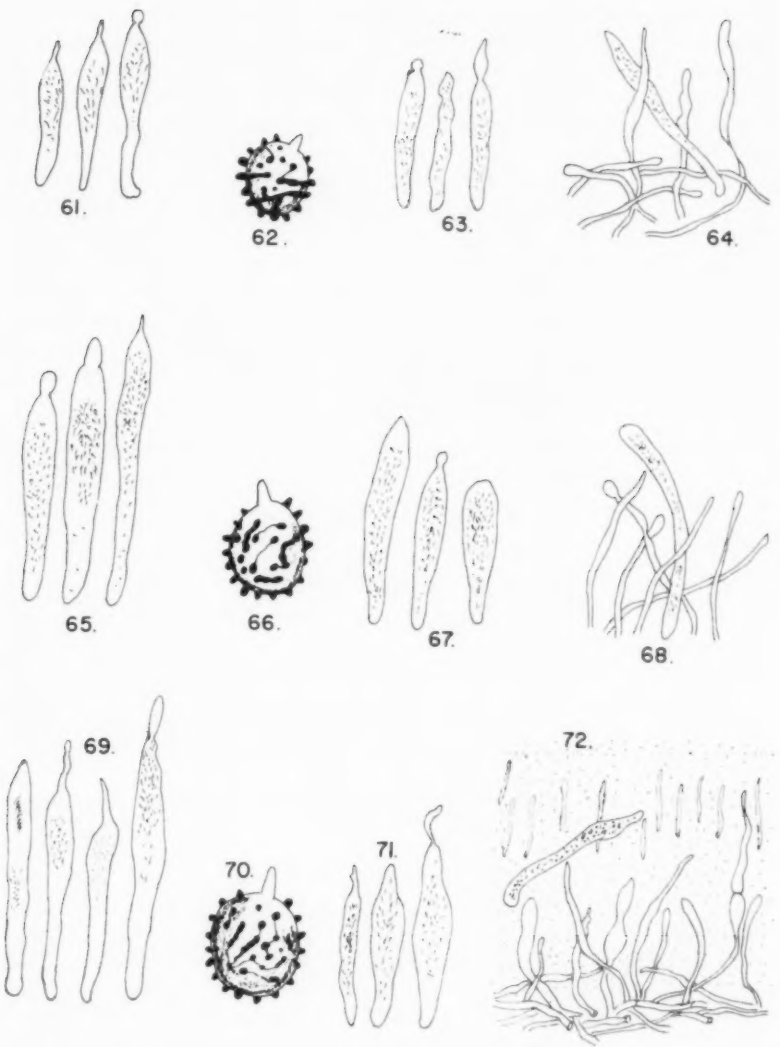
Singer (**1957**) would expect this species to be near *R. variegata* Sing.

R. HUMIDICOLA Burl., North American Flora **9**: 230. 1915. *Spores* (FIG. 62) 7–8 × 5.5–6.5 μ, ellipsoid, warts 0.4–1.0 μ high, bands and lines forming a complete or incomplete reticulum, warts rarely isolated. *Pleurocystidia* (FIG. 61) 40–52 × 7–8 μ, clavate or fusoid, mucronate, capitate or appendiculate, banded; *cheilocystidia* (FIG. 63) 40–50 × 4–8 μ, cylindric or clavate, acute, capitate, or appendiculate, banded. *Subhymenium* of small cells. *Epicutis* (FIG. 64) more or less of the *emetica*-type: the hyphae erect to repent and tangled, *pilocystidia* neither very abundant nor very conspicuous. *Hypodermium* not distinct.

Singer (**1942**) finds the spores slightly larger than reported above.

R. MARGINATA Burl., Mycologia **28**: 257. 1936. *Spores* (FIG. 66) 7.5–10 × 6.7 μ, ellipsoid, often inequilateral, warts 0.3–0.5 μ high, isolated or catenulate, more rarely with an occasional, inconspicuous fine line. *Pleurocystidia* (FIG. 65) 70–96 × 7–10 μ, clavate to subcylindric, appendiculate, numerous, granular or banded; *chleilocystidia* (FIG. 67) 35–58 × 5–9 μ, clavate, acute or appendiculate, banded. *Subhymenium* of small cells. *Epicutis* (FIG. 68) more or less of the *emetica*-type. *Hypodermium* narrow, and not sharply differentiated.

R. MAXIMA Burl., North American Flora **9**: 229. 1915. *Spores* (FIG. 70) 9–11(–12) × 7.5–9 μ, ellipsoid, warts 0.3–0.5(–0.9) μ high, isolated or a few short-catenulate, many with fine lines forming a reticu-



FIGS. 61–64: *Russula humidicola*. 61. Pleurocystidia. 62. Spore. 63. Cheilocystidia. 64. Epicutis. FIGS. 65–68: *Russula marginata*. 65. Pleurocystidia. 66. Spore. 67. Cheilocystidia. 68. Epicutis. FIGS. 69–72: *Russula maxima*. 69. Pleurocystidia. 70. Spore. 71. Cheilocystidia. 72. Epicutis.

lum. *Pleurocystidia* (FIG. 69) 62–90 × 6–10 μ, clavate to subcylindric, acute or appendiculate, granular or banded; *cheilocystidia* (FIG. 71) 40–65 × 4–11 μ, subcylindric, clavate, or fusoid, acute or appendiculate, banded. *Subhymenium* of small cells. *Epicutis* (FIG. 72) a turf of short, erect, gelatinous hyphae, with scattered more or less gelatinized hyphae in the glutinous zone above the turf; *pilocystidia* few. *Hypodermium* none.

R. MEXICANA Burl., Mycologia **3**: 26. 1911. *Spores* (FIG. 75) 8.5–10 × 8–9 μ, ellipsoid to subglobose, warts 0.3–0.8 μ high, with some short bands, a few fine lines. *Pleurocystidia* (FIG. 73) 60–110 × 8–12 μ, fusoid, more or less obtuse or subcapitate, banded; *cheilocystidia* (FIG. 74) 45–72 × 5–7 μ, subcylindric to clavate, banded. *Subhymenium* of small flattened cells. *Epicutis* (FIG. 76) a broad zone of gelatinous, more or less repent, interwoven hyphae, with numerous *pilocystidia* imbedded in or at times on the surface of the epicutis. *Hypodermium* well-developed (FIG. 76).

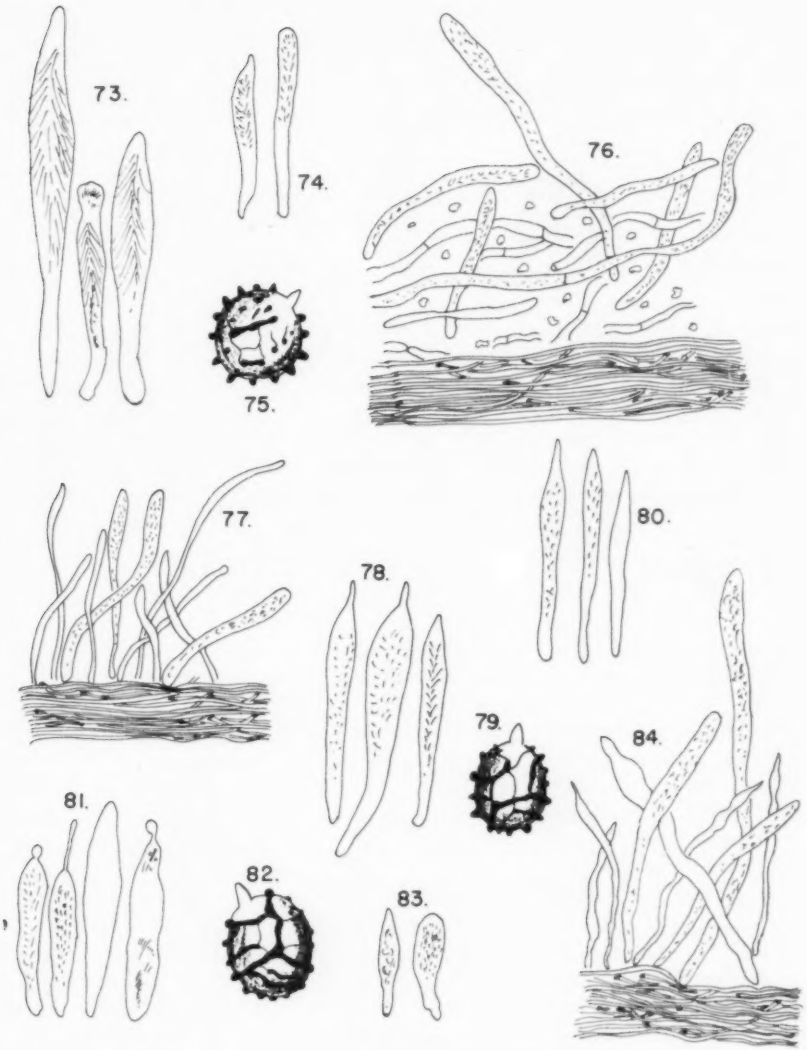
Singer (**1942**) finds the spores to be slightly smaller than reported above. He concludes from his study of the type that it is a synonym of *R. luteotacta* Rea; subsequently (**1951**) he expresses some doubt on this point.

R. MORDAX Burl., Mycologia **28**: 258. 1936. *Spores* (FIG. 79) 7–9.5 × 6–7.5 μ, ellipsoid, warts 0.4–0.8 μ high, connected by bands and an occasional fine line. *Pleurocystidia* (FIG. 78) 67–78 × 6–12 μ, clavate, acute or appendiculate, banded; *cheilocystidia* (FIG. 80) 52–63 × 4–6 μ, clavate or subcylindric, acute or nearly appendiculate, empty or banded. *Subhymenium* of small cells. *Epicutis* (FIG. 77) of the *emetica*-type; *pilocystidia* conspicuous. *Hypodermium* distinct (FIG. 77).

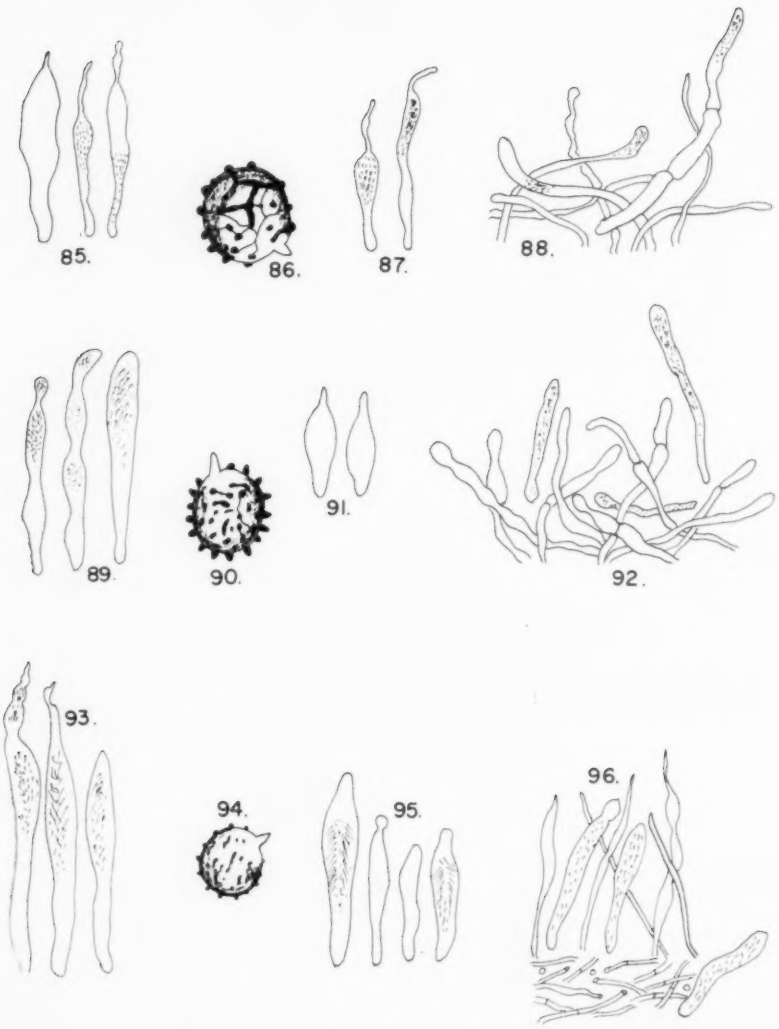
Singer (**1942**) expresses the conviction that *R. mordax* is *R. badia* Quél.

R. MURINA Burl., Mycologia **28**: 254. 1936. *Spores* (FIG. 82) 8.5–11 × 7.5–8.5 μ, ellipsoid, warts 0.2–0.4 μ, rather short and blunt, bands and a few lines form a complete or partial reticulum. *Pleurocystidia* (FIG. 81) 42–61 × 8–11 μ, scattered, more numerous near the edges, clavate or fusoid, acute, capitate or appendiculate, empty or banded; *cheilocystidia* (FIG. 83) 28–30 × 5–8 μ, fusoid or clavate, banded, few. *Subhymenium* of small cells. *Epicutis* (FIG. 84) of the *emetica*-type; *pilocystidia* numerous. *Hypodermium* distinct (FIG. 84).

R. MURRILLII Burl., Mycologia **5**: 310. 1913. *Spores* (FIG. 86) 8.5–10 × 7–8.5 μ, ellipsoid, at times subglobose, warts 0.1–0.3(–0.4) μ high, more rarely the wall nearly smooth, with bands and fine lines forming a reticulum, a few warts isolated. *Pleurocystidia* (FIG. 85)



FIGS. 73–76: *Russula mexicana.* 73. Pleurocystidia. 74. Cheilocystidia. 75. Spore. 76. Epicutis. FIGS. 77–80: *Russula mordax.* 77. Epicutis. 78. Pleurocystidia. 79. Spore. 80. Cheilocystidia. FIGS. 81–84: *Russula murina.* 81. Pleurocystidia. 82. Spore. 83. Cheilocystidia. 84. Epicutis.



FIGS. 85–88: *Russula murrillii*. 85. Pleurocystidia. 86. Spore. 87. Cheilocystidia. 88. Epicutis. FIGS. 89–92: *Russula operta*. 89. Pleurocystidia. 90. Spore. 91. Cheilocystidia. 92. Epicutis. FIGS. 93–96: *Russula ornaticeps*. 93. Pleurocystidia. 94. Spore. 95. Cheilocystidia. 96. Epicutis.

48–57 × 5–10 μ, at times inconspicuous, irregularly subcylindric to clavate, appendiculate, empty or banded; *cheilocystidia* (FIG. 87) 42–55 × 4–6 μ, irregularly clavate, appendiculate, somewhat banded, at times inconspicuous. *Subhymenium* of small cells. *Epicutis* (FIG. 88) an ixotrichodermium of erect to semi-erect hyphae, some hyphae broad and septate, the terminal elements are *pilocystidia*. *Hypodermium* poorly developed or none.

Singer (**1957**) concludes that this species is close to *R. punctata* which constantly has paler spores.

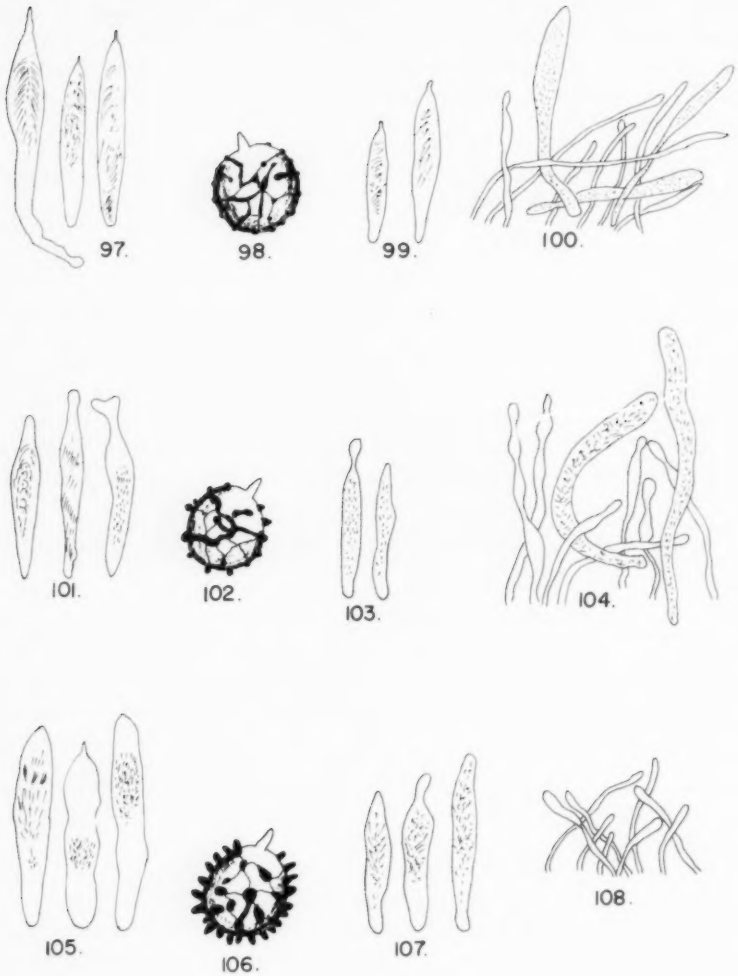
R. OPERTA Burl., Mycologia **16**: 18. 1924. *Spores* (FIG. 90) 7–9 × (5–)7–8 μ, ellipsoid to subovoid, warts 0.3–0.8 μ high, isolated, or a few short-catenulate, others with a few short lines. *Pleurocystidia* (FIG. 89) 54–65 × 5–9 μ, clavate or more often cylindric-constricted, obtuse or more or less capitate, granular or banded, not conspicuous, rare in some sections; *cheilocystidia* (FIG. 91) 28–32 × 7–8 μ, fusoid to bottle-shaped, somewhat appendiculate, empty, few. *Subhymenium* of small cells. *Epicutis* (FIG. 92) of irregular or constricted erect or repent, gelatinous hyphae, with inconspicuous *pilocystidia*. *Hypodermium* not developed.

Singer (**1957**) places this and two other species in synonymy with *R. pusilla* Pk.

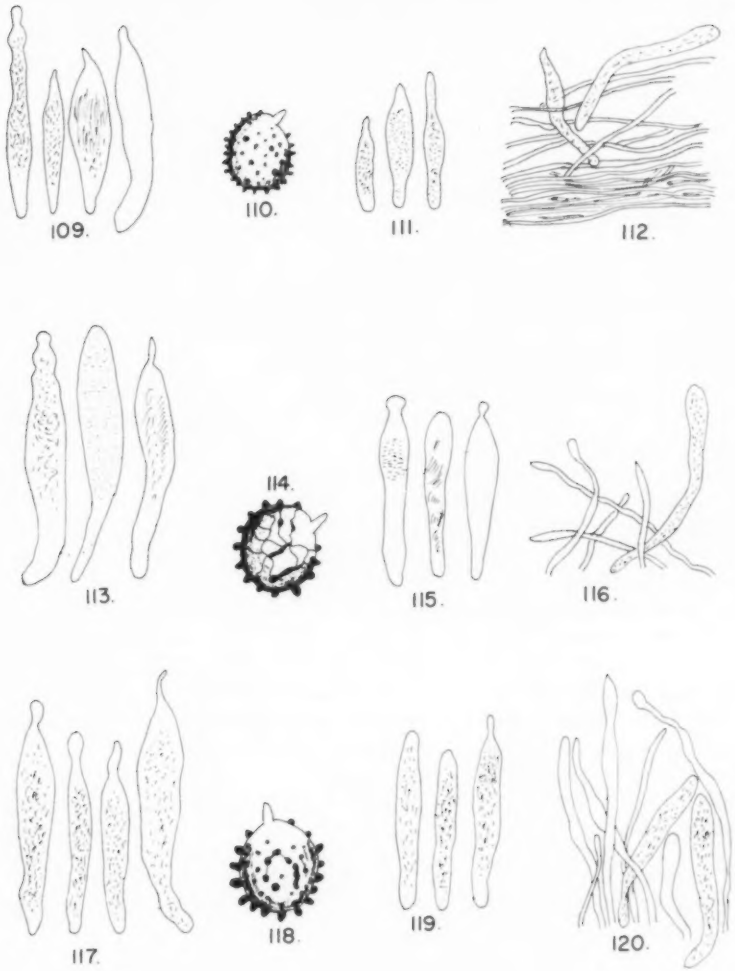
R. ORNATICEPS Burl., Mycologia **13**: 130. 1921. *Spores* (FIG. 94) 6–7.5(–9) × 5–6(–7) μ, ellipsoid, warts variable: some as punctations (or the spore-wall nearly smooth), others 0.1–0.4(–0.6) μ high, a few catenulate, with a few inconspicuous fine lines. *Pleurocystidia* (FIG. 93) 63–93 × 7–10 μ, more or less fusoid, acute or constricted-appendiculate, banded; *cheilocystidia* (FIG. 95) 33–54 × 5–8 μ, more or less clavate, obtuse to capitate, empty or banded. *Epicutis* (FIG. 96) an ixotrichodermium; *pilocystidia* conspicuous. No well-defined *hypodermium*.

R. PARVULA Burl., North American Flora **9**: 235. 1915. *Spores* (FIG. 98) 7–9 × 6–8 μ, globose, subglobose, or ellipsoid, warts 0.1–0.3 μ high, bands and lines forming a complete or partial reticulum. *Pleurocystidia* (FIG. 97) 48–80 × 7–10 μ, more or less clavate or subcylindric, mucronate or tapering, banded; *cheilocystidia* (FIG. 99) 34–45 × 5–6 μ, clavate or subfusoid, mucronate, banded. *Subhymenium* of small cells. *Epicutis* (FIG. 100) a broad zone of gelatinous hyphae, with numerous more or less erect hyphae and abundant *pilocystidia*. *Hypodermium* present.

R. PLACITA Burl., Mycologia **28**: 253. 1936. *Spores* (FIG. 102) 7–9 × 6–7.5 μ, ellipsoid to subglobose, warts 0.5–0.8 μ high, bands and



FIGS. 97–100: *Russula parvula*. 97. Pleurocystidia. 98. Spore. 99. Cheilocystidia. 100. Epicutis. FIGS. 101–104: *Russula placita*. 101. Pleurocystidia. 102. Spore. 103. Cheilocystidia. 104. Epicutis. FIGS. 105–108: *Russula pracumbonata*. 105. Pleurocystidia. 106. Spore. 107. Cheilocystidia. 108. Epicutis.



FIGS. 109–112: *Russula redolens.* 109. Pleurocystidia. 110. Spore. 111. Cheilocystidia. 112. Epicutis. FIGS. 113–116: *Russula robinsoniae.* 113. Pleurocystidia. 114. Spore. 115. Cheilocystidia. 116. Epicutis. FIGS. 117–120: *Russula rubriochracea.* 117. Pleurocystidia. 118. Spore. 119. Cheilocystidia. 120. Epicutis.

lines forming a partial or complete reticulum. *Pleurocystidia* (FIG. 101) 46–54 × 7–8 μ, fusoid or subclavate, acute or capitate, at times the apex irregularly shaped, banded; *cheilocystidia* (FIG. 103) 43–47 × 5–6 μ, subfusoid, acute or appendiculate-capitate, banded. *Subhymenium* of small, flattened cells. *Epicutis* (FIG. 104) a broad ixotrichodermium, with *pilocystidia*, resting on an *hypodermium*.

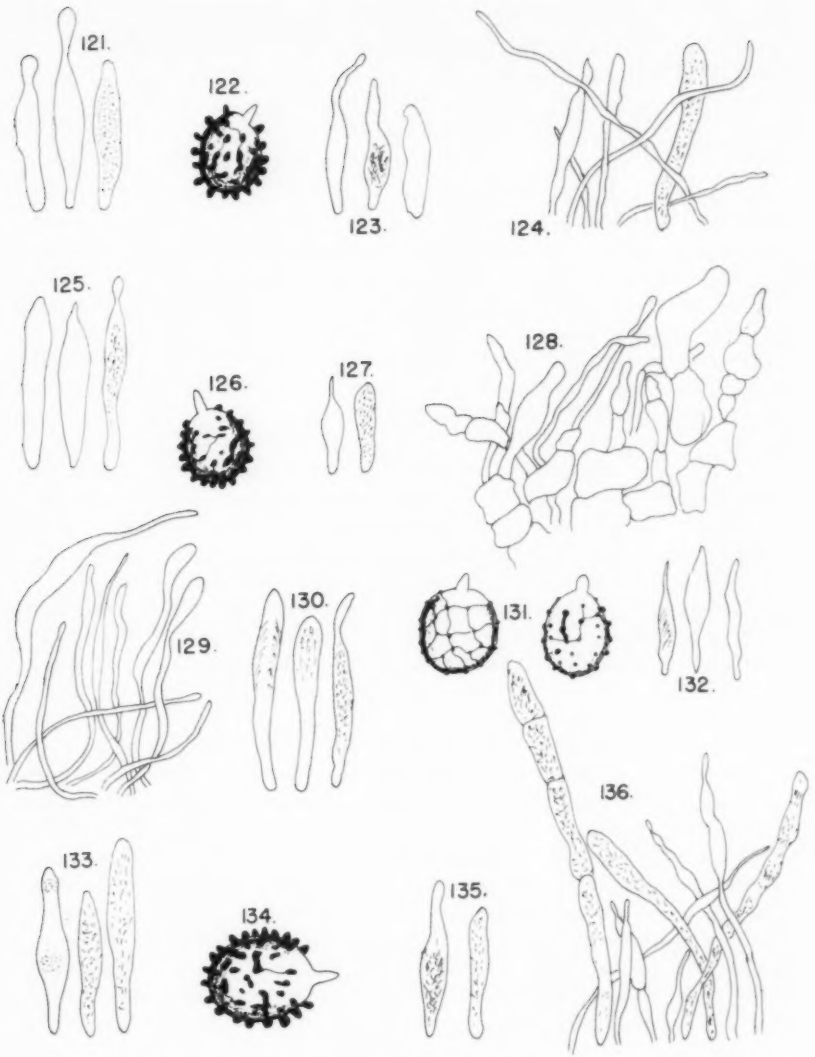
R. PRAEUMBONATA Burl., Mycologia **13**: 134. 1921. *Spores* (FIG. 106) 8.5–11.5 × 7–9.5 μ, ellipsoid, warts numerous and large, 0.8–1.3 μ high, with numerous fine lines and a few bands forming a complete or partial reticulum. *Pleurocystidia* (FIG. 105) 52–60 × 8–10 μ, clavate or subfusiform, rounded or mucronate, more or less banded, scattered and not very conspicuous, more abundant toward the edges; *cheilocystidia* (FIG. 107) 40–52 × 6–8 μ, clavate, subfusoid, acute or appendiculate, banded, at times numerous. *Subhymenium* of few cells, mostly hyphoid. *Epicutis* (FIG. 108) an ixotrichodermium, hyphae relatively short; no *pilocystidia* and no well-developed *hypodermium*.

R. REDOLENS Burl., Mycologia **13**: 133. 1921. *Spores* (FIG. 110) 7–8.5 × 5–6.3 μ, ellipsoid, warts 0.3–0.6(–0.7) μ high, isolated, at times there is an appearance of some faint fine lines. *Pleurocystidia* (FIG. 109) 40–63 × 5–11 μ, fusoid, clavate, irregular and constricted, empty or banded, apices appendiculate or sub-obtuse, usually buried, scattered, inconspicuous; *cheilocystidia* (FIG. 111) 27–38 × 5–7 μ, fusoid, obtuse or at times more or less appendiculate, granular or banded, few. *Subhymenium* of small cells. *Epicutis* (FIG. 112) a broad ixocutis with a few inconspicuous *pilocystidia*, and an *hypodermium* (FIG. 112).

R. ROBINSONIAE Burl., North American Flora **9**: 221. 1915. *Spores* (FIG. 114) 8–9.5 × 6–8 μ, ellipsoid, warts 0.3–0.6 μ high, some catenulate, fine lines forming a partial or complete reticulum. *Pleurocystidia* (FIG. 113) 68–73 × 10–12 μ, clavate, appendiculate, or obtuse to semiacute, granular or banded; *cheilocystidia* (FIG. 115) 48–53 × 7–9 μ, clavate, obtuse or capitate, empty, granular, or banded. *Subhymenium* of small cells. *Epicutis* (FIG. 116) of the *emetica*-type; *pilocystidia* not conspicuous.

Singer (**1942**) reports dermatocystidia as very abundant. He compares this species with the European *R. helodes* Melzer, and also points out its resemblance to *R. queletii*.

R. RUBRIOCHRACEA Murr., Mycologia **4**: 293. 1912. *Spores* (FIG. 118) 8–10.5 × 6–8(–9) μ, ellipsoid to subglobose, warts 0.6–1.2 μ high, isolated or, in some spores, with a few faint fine lines. *Pleurocystidia* (FIG. 117) 54–74 × 8–13 μ, clavate to subcylindric, densely and minutely banded, apices appendiculate or more often capitate; *cheilocystidia* (FIG. 119) 44–56 × 6–8 μ, clavate or subcylindric, obtuse or subacute, more rarely appendiculate, densely granular-banded. *Subhymenium* of small,



FIGS. 121–124: *Russula stricta*. 121. Pleurocystidia. 122. Spore. 123. Cheilocystidia. 124. Epicutis. FIGS. 125–128: *Russula subtilis*. 125. Pleurocystidia. 126. Spore. 127. Cheilocystidia. 128. Epicutis. FIGS. 129–132: *Russula sulcatipes*. 129. Epicutis. 130. Pleurocystidia. 131. Spores. 132. Cheilocystidia. FIGS. 133–136: *Russula zelleri*. 133. Pleurocystidia. 134. Spore. 135. Cheilocystidia. 136. Epicutis.

flattened cells. *Epicutis* (FIG. 120) a broad zone of gelatinous hyphae, the surface hyphae erect or ascendant. *Pilocystidia* numerous. No *hypodermium*.

Singer (**1942**) suggests its close relationship to acrid forms of *R. xerampelina*.

R. STRICTA Murr., Mycologia **4**: 166. 1912. *Spores* (FIG. 122) 7–9 × 6–7 μ, ellipsoid, warts 0.5–1.0 μ high, isolated, or some catenulate, occasionally with a few fine lines. *Pleurocystidia* (FIG. 121) 42–58 × 7–8 μ, clavate or fusoid, obtuse or appendiculate, empty or banded; *cheilocystidia* (FIG. 123) 32–50 × 6–8 μ, fusoid, or subclavate, obtuse or appendiculate, empty or banded. *Subhymenium* a narrow zone of small, flattened cells. *Epicutis* (FIG. 124) a thick zone of gelatinous hyphae, the surface hyphae erect or ascendant, with a few inconspicuous *pilocystidia*. *Hypodermium* present.

R. SUBTILIS Burl., Mycologia **16**: 20. 1924. *Spores* (FIG. 126) 7–9 × (5.5–)6–7 μ, ellipsoid, warts 0.3–0.7 μ high, isolated or with some fine lines and chains of warts forming a partial reticulum. *Pleurocystidia* (FIG. 125) 47–52 × 6–10 μ, quite inconspicuous, clavate or subcylindric, acute or appendiculate, empty or banded; *cheilocystidia* (FIG. 127) few, 25–29 × 7 μ, clavate or flask-shaped, empty or granular, obtuse or appendiculate. *Subhymenium* of relatively large cells. *Epicutis* (FIG. 128) of numerous more or less erect or ascendant, nongelatinous hyphae which are irregularly shaped, arising from sphaerocysts, giving a loose, pseudoparenchymatous appearance, often the upper elements constricted and septate. No *pilocystidia*.

R. SULCATIPES Murr., Mycologia **4**: 291. 1912. *Spores* (FIG. 131) 7–9 × 6–7.5 μ, ellipsoid or subglobose, warts variable: on some spores the warts 0.1–0.6 μ high, on most spores about 0.1 μ high, at times the type is IIIa, or again IV, more rarely VI. *Pleurocystidia* (FIG. 130) 50–56 × 5–8 μ, clavate or slender-fusoid, obtuse, acute, or long-appendiculate, banded, very inconspicuous, few, slightly more numerous near the edges; *cheilocystidia* (FIG. 132) 32–37 × 3–7 μ, fusoid, cylindric, acute or appendiculate, empty or banded, rare (absent many sections). *Subhymenium* of small cells. *Epicutis* (FIG. 129) a trichodermium, hyphae appearing slightly gelatinous and nonseptate; *hypodermium* present. *Pilocystidia* none.

Singer (**1942**) has suggested that this species may be merely a form of *R. mariae*.

R. ZELLERI Burl., Mycologia **28**: 256. 1936. *Spores* (FIG. 134) 8.5–11(–12–13) × 7–9(–10) μ, ellipsoid, warts 0.4–0.8 μ high, isolated or catenulate, an occasional fine line. *Pleurocystidia* (FIG. 133) 40–56

× 5–8 μ, fusoid or nearly bottle-shaped, acute, granular or banded; *cheilocystidia* (FIG. 135) 36–44 × 5–6 μ, clavate to bottle-shaped, obtuse or more or less appendiculate, banded. *Subhymenium* of small cells. *Epicutis* (FIG. 136) a turf of gelatinous, more or less constricted hyphae, the terminal element often acute, with numerous *pilocystidia*, some of which are septate. *Hypodermium* present.

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REVIEWS

THE STIPITATE HYDNUMS OF NOVA SCOTIA, by Kenneth A. Harrison. 80 p., 30 fig. col. Canada Dept. Agr. Res. Branch Publ. 1099, Ottawa. April, 1961. Price $5.00.

It has been obvious at least since Wehmeyer's reports of some twenty years ago that Nova Scotia is an unusually favorable region for the study of the pileate hydnums. Since 1950, Harrison has taken advantage of an opportunity that is apparently unique in northeastern North America. He has had an abundance of material and has been able to study the development of fruit-bodies from the earliest stages through to maturity and senescence, under varying conditions of moisture and temperature. With these advantages, several problems or confusions of species have been solved or elucidated.

This publication is not a taxonomic treatment but a manual. The author has not attempted to follow the most recent ideas of family arrangements (cf. Donk), but has treated that group of spinulose hymenomycetes of interest to many collectors and long so puzzling. He has, however, followed a good, up-to-date scheme of genera and species. As to genera, this reviewer is glad to see his use of *Dentinum* for the *repandum* series, and *Hydnum* for *H. imbricatum*, etc., instead of *Hydnum* and *Sarcodon*, respectively. The nomenclature of species and varieties is that made familiar to us recently by Maas Geesteranus, as is likewise the arrangement of these taxa, with two modifications—*Phellodon alboniger* as a variety of *P. niger*, and vars. *scrobiculatum* and *zonatum* in *Hydnellum scrobiculatum* instead of as two of the four varieties of *H. velutinum*.

The treatment covers 32 species and four varieties, including three or four not yet found but likely to occur in Nova Scotia, and seven new species. Only four other species names will appear as new to those who have not kept up with the most recent nomenclatorial changes. No descriptions are given for nine of the taxa and the descriptions of seven more are very brief or merely notes; the author has explained (p. 17) that he has omitted detailed characterizations of genera and species unless the Nova Scotia material differs from that described in the manual of Coker and Beers. Discussions follow most of the descriptions. In

the keys, the criteria are very brief but clear and plain, and apparently adequate for satisfactory distinguishment.

In the introduction, the Province of Nova Scotia is discussed geologically, climatically, botanically and mycologically, and there are sections upon the stipitate hydnums as a group, the development of the sporophore, the influence of weather upon the sporophore, and nomenclature. A good literature list is added. The index is complete. The illustrations consist of three plates of 30 figures very well reproduced from color photographs.

This manual will be useful, as is, at least for New Brunswick, Quebec, eastern Ontario, and northern Maine and New Hampshire. With the addition of ten or a dozen species, one would have the coverage of the remainder of the New England states and New York and Pennsylvania, and possibly other northern states. It very definitely should be consulted by users of the work by Coker and Beers. It is a careful, thorough, competent study, with important additions to our knowledge of certain species, and with common-sense interpretations of species and their varieties.—WALTER H. SNELL.

PHYTOCHEMISTRY, An International Journal of Plant Biochemistry. Quarterly. Pergamon Press, New York. Subscription rates: $20.00 per volume for libraries, industry, government establishments, etc.; $10.00 for individuals who order direct from publisher and certify that the journal is for their personal use.

The foreword to volume 1, number 1 (October, 1961) provides an appropriate introduction for a review: "We believe that the the appearance of a new journal covering the area of plant biochemistry will be generally welcomed by those whose work lies in this field. . . ." What is meant by plant biochemistry is not defined exactly. The foreword seems to imply that "plant" refers only to higher plants, since it distinguishes between "plants," animals and microorganisms." However, one of the papers in this first number of the journal deals with the carotenoids of *Rhizophlyctis rosea*, a phycomycete. It is perhaps best to consider that the purpose of the journal is reflected in the "Notes for Contributors," in which especially those papers are invited ". . . which have as their basis a deeper understanding of the factors underlying the development and differentiation of plants and the chemistry of plant products." The question of what is included in "plants" will then be less important than the purpose of the research. The medicinal properties of a product

obtained from a higher plant might accordingly be a less appropriate subject than the chemistry and metabolism (by the mold) of a mold product.

The list of editors and Editorial Advisory Board members represents a laudable union of nationalities, as well as of appropriate scientific disciplines: botany, biochemistry and organic chemistry.—MARJORIE ANCHEL.

CONTEMPORARY BOTANICAL THOUGHT, by Anna M. MacLeod and L. S. Cobley, ix + 197 p., 22 figs. Quadrangle Books, Inc., Chicago, Illinois, 1962. Price, $6.50.

This stimulating collection of eight essays based on a series of lectures sponsored by the Botanical Society of Edinburgh should be welcomed by anyone who considers himself a botanist. The titles of the individual papers span the field of Botany: Morphology, C. W. Wardlaw; Taxonomy, J. S. Gilmour; Genetics, Kenneth Mathew; Evolution, E. J. H. Corner; Ecology, A. S. Watt; Mycology, N. F. Robertson; Physiology, Merion Thomas; and Plant Cell Structure, Irene Manton. The tone is equally varied, ranging from J. S. Gilmour's thoughtful and provocative consideration of categories of classification, the most ancient and still a most central problem in biology, to the almost breathless contemporaneousness of Irene Manton's discussion of the impact of electron microscopy on the study of intra-cellular anatomy.

Of particular interest to mycologists is N. F. Robertson's presentation of the current state of our knowledge of the structure, growth, and differentiation of vegetative hyphae and his timely suggestions for further exploration needed in this field. His discussion of fungal "cells" and their components makes it clear that one should be very cautious in drawing analogies between these structures and those of higher plants or animals.

The fungi also receive due credit for their role in contemporary genetic studies in Kenneth Mathew's survey of the development of our knowledge of hereditary mechanisms.

In an era when botanists are forced to specialize, here is a most pleasant way to come abreast of developments in specialties other than our own. Despite the compactness of the individual essays, the authors' excitement about their topics comes through with a warmth that inspires the reader.—W. C. DENISON.

DEMATIACEOUS HYPHOMYCETES. III, by M. B. Ellis. 55 p., 35 figs. Mycological Papers, No. 82. Commonwealth Mycological Institute, Kew. December, 1961. Price, 20s.

Twenty-one classical and new taxa of *Helminthosporium* and *Exosporium* receive extensive description and documentation in this latest paper of a series designed to cover some large confusing genera as well as other relatively small genera of dark-spored Hyphomycetes. (*Vide* Mycol. Papers Nos. 76 and 79. 1960 and 1961.) Ellis maintains that these two genera exhibit fundamentally different types of conidiophore development although they are superficially very similar. The developmental morphology of *Exosporium* conidiophores is considered to be the same as that of many graminicolous species of "*Helminthosporium*" currently disposed in *Drechslera* and *Bipolaris*. Two new genera, *Curvulariopsis* and *Pendulispora*, are described and elegantly illustrated. Several new species, combinations, and names are established in seven other dematiaceous genera.—E. G. SIMMONS.

COELOMYCETES. I, by B. C. Sutton. 16 p., 7 figs., 2 pl. Mycological Papers, No. 80. Commonwealth Mycological Institute, Kew. November, 1961. Price, 5s.

The developmental morphology of conidia and conidiophores in *Pestalotiopsis* is stressed as an introduction to taxonomic observations on five taxa of the genus (including three comb. nov.). Of major importance are the descriptions and illustrations of the endogenous origin of conidia and of the annellations formed successively as each spore is liberated. These basic characters have been missed or ignored in all major publications on *Pestalotiopsis* and *Pestalotia* and are reported previously only in a brief article (D. Ritchie, Mycologia **52**: 655–658. 1960 [1961]). Such observations will prove particularly significant if they are extended and used in establishing a rapprochement between the monographic views of E. F. Guba and R. L. Steyaert on these genera.—E. G. SIMMONS.

FUNGI IN OCEANS AND ESTUARIES, by T. W. Johnson, Jr., and F. K. Sparrow, Jr. xxii + 668 p., 19 tab., 7 text figs., 17 plates with 312 figs. J. Cramer, Weinheim, 1961. Price, $30.00.

The first fungus indisputably found in marine waters was described about 1846. Since that time a constantly increasing volume of literature has accumulated. Until the publication of this book, however, there has

not been available a single authoritative source of information about these fungi, or their biology. In my experience it has been necessary to learn the techniques for collecting, isolation, and identification by reading a number of papers, or from personal communication with those interested in these organisms. This excellent text is indeed welcome as it compiles the facts and describes the complex and interlocking aspects of marine mycology.

The text is in two parts. The opening section describes the groups of fungi, methods of collection, isolation, and culture, and occurrence and geographic distribution. An historical résumé is followed by a lengthy discussion of the general biological activities of marine fungi. (The word "marine" is used in its broadest sense by this reviewer.) This material is followed by chapters on physiology and ecology. An especially interesting one on economic significance closes the part.

Part II introduces a systematic treatment of the marine fungi. Fortunately, the authors have concentrated upon the practicalities of identification. They state that, "it (this section) is intended primarily for the marine biologist." To this end, two pages of the text and 81 figures define and illustrate the descriptive terminology for the various classes of fungi. The figures are excellently drawn and immediately clarify usage.

The systematic account includes well constructed keys to classes, orders, genera, and species. They appear to be workable at least for the 10–12 identifications which I made using organisms known and unknown to me.

Appendix A lists the fungi previously reported as terrestrial or fresh water species which have also been isolated from marine substrata. Appendix B lists by author citation a number of incompletely identified species reported in the literature.

A bibliography of approximately 800 citations and the explanation of plates and index conclude the book.

It is a pleasure to have at last one comprehensive and definitive book which deals with the taxonomy and biology of marine fungi. This assemblage of the many facts concerning these fungi has brought coherency to this particular field of study. The authors are certainly to be complimented on a thorough job, magnificently done.

I am not enthusiastic about the type of print used. It is difficult for me to read. The margins seem unusually wide and the book might not have been so bulky if narrower margins had been used.

This is an excellent book, beautifully done and a credit to its authors. —A. W. ZIEGLER.

STUDIES OF PYRENOMYCETES: VI. THIELAVIA, WITH NOTES ON SOME ALLIED GENERA, by C. Booth. 15 p., 1 pl., 5 figs. Mycological Papers, No. 83. Commonwealth Mycological Institute, Kew. 27 Dec. 1961. Price, 5s.

Dr. Booth continues his excellent series of papers on pyrenomycetes by considering the groups of dark amerosporous genera centering around *Thielavia*, usually placed in the Eurotiales. A key to 8 genera is included: the genera *Thielavia* with 10 taxa (2 new species), *Pseudeurotium* with 7 species (1 new), and *Cephalotheca* with 4 species are discussed in detail.—CLARK T. ROGERSON.

HOST LISTS OF KENYA FUNGI AND BACTERIA, by R. M. Nattrass. 46 p. Mycological Papers, No. 81. Commonwealth Mycological Institute, Kew. 27 Dec. 1961. Price, 12s. 6d.

This is an up-to-date list of the fungi and bacteria of Kenya compiled from published lists and from the collections and records in the Department of Agriculture, Nairobi. The fungi are listed under phanerogamic hosts arranged alphabetically, under fungus hosts, and under other substrata. Bacterial pathogens are listed; references and an index of fungi and bacteria are included.—CLARK T. ROGERSON.

INDEX TO VOLUME LIII

INDEX TO AUTHORS AND TITLES

Anastasiou, C. J. Fungi from salt lakes. I. A new species of Clavariopsis 11

Anderson, N. A. See Miller and Anderson 433

Aoshima, Kiyowo, Paul L. Lentz, and Hazel M. McKay. Stereum taxodii in Japan and Formosa 145

Autery, Charlotte L. See Johnson and Autery 432

Ayers, T. T. See Lambert and Ayers 304

Backus, M. P. See Christensen and Backus 451

——, **and P. A. Orpurt.** A new Emericellopsis from Wisconsin, with notes on other species 64

Baxter, John W. North American species of Puccinia on Hyptis 17

Beneke, Everett S. See Bulmer and Beneke 123; see Sedlmayr et al. 98, 558

Benjamin, Chester R. See Stevenson and Benjamin 438

Berliner, Martha D. Studies in fungal luminescence 84

Bridges, Charles H. See Emmons and Bridges 307

Buck, Robert W. Mushroom poisoning since 1924 in the United States 537

Bulmer, Glenn S., and Everett S. Beneke. Studies on Calvatia gigantea. I. Germination of the basidiospores 123

Chandrasekaran, S. See Rangaswami and Chandrasekaran 371

Christensen, Martha, and M. P. Backus. New or noteworthy Penicillia from Wisconsin soils 451

Cobb, F. W., Jr., C. L. Fergus, and W. J. Stambaugh. The effect of temperature on ascogonial and perithecial development in Ceratocystis fagacearum 91

Cooke, Wm. Bridge. The genus Schizophyllum 575

Cowley, G. T., and W. F. Whittingham. The effect of tannin on the growth of selected soil microfungi in culture 539

Cox, Elsie A. See Goos et al. 262

Coy, D. O. See Tuveson and Coy 244

Dick, Esther A. See Snell and Dick 228

Drechsler, Charles. Production of large solitary sporangiospores in some species of the Mucorales 439

——. Two species of Conidiobolus often forming zygospores adjacent to antheridium-like distentions 278

Ellis, J. J. See Hesseltine and Ellis 406

Emmons, Chester W. Mycology and medicine 1

——, **and Charles H. Bridges.** Entomophthora coronata, the etiologic agent of a phycomycosis of horses 307

Etheridge, D. E. See Pomerleau and Etheridge 155

Evenson, Adelaide E. A preliminary report of the Myxomycetes of southern Arizona 137

Fergus, C. L. See Cobb et al. 91

Fidalgo, M. E. P. Kauffmann. The genus Phaeodaedalea 201

Gerdemann, J. W. A species of Endogone from corn causing vesicular-arbuscular mycorrhiza 254
Ghosh, Gouri Rani, G. F. Orr, and H. H. Kuehn. A re-evaluation of Arachniotus indicus 221
Gilbertson, Robert L. See Lowe and Gilbertson 474
Gilkey, Helen Margaret. New species and revisions in the order Tuberales 215
Goos, Roger D., Elsie A. Cox, and G. Stotzky. Botryodiplodia theobromae and its association with Musa species 262
Gordee, R. S., and C. L. Porter. Structure, germination, and physiology of microsclerotia of Verticillium albo-atrum 171
Hacskaylo, E. See Vozzo and Hacskaylo 538
Hesler, L. R. A study of Russula types, II 605
Hesseltine, C. W., and J. J. Ellis. Notes on Mucorales, especially Absidia 406
Jellison, William L., and J. William Vinson. The distribution of Emmonsia crescens in Europe 524
Johnson, T. W., Jr., and Charlotte L. Autery. An Arthrobotrys from brackish water 432
Kevorkian, Arthur G. Illustration of Elsinoë boucheae 437
Knight, S. G. See Meyers and Knight 115
Korf, Richard P. See Noviello and Korf 237
Kuehn, H. H. See Ghosh et al. 221
Lambert, E. B., and T. T. Ayers. Basidiospores of several species of Agaricales discharged and collected in pairs 304
Lentz, Paul L. See Aoshima et al. 145
Leppik, E. E. Some viewpoints on the phylogeny of rust fungi. IV. Stem rust genealogy 378
Liberta, Anthony E. A taxonomic analysis of section Athele of the genus Corticium. II 443
Lowe, Josiah L., and Robert L. Gilbertson. Synopsis of the Polyporaceae of the western United States and Canada 474
McAlear, James H. See Moore and and McAlear 194
McKay, Hazel H. See Aoshima et al. 145
Martin, G. W. The genus Schenella 25
Mathre, Judith H. See Tiffany and Mathre 600
Mehrotra, B. S., and M. D. Mehrotra. A new species of Choanephora from India 464
Mehrotra, M. D. See Mehrotra and Mehrotra 464
Meyers, E., and S. G. Knight. Studies on the intracellular amino acids of Penicillium roqueforti 115
Miller, C. W., and N. A. Anderson. Proliferation of conidiophores and intrahyphal hyphae in Aspergillus niger 433
Moore, Royall T., and James H. McAlear. Fine structure of Mycota. 5. Lomasomes—previously uncharacterized hyphal structures 194
Noviello, Carmine, and Richard P. Korf. A simple technique for investigating stromatal formation in the Sclerotiniaceae 237
Okudaira, Masahiko, and Jan Schwarz. Infection with Histoplasma duboisii in different experimental animals 53
Orpurt, P. A. See Backus and Orpurt 64
Orr, G. F. See Ghosh et al. 221

Peterson, Roger S. Notes on western rust fungi. I. Chrysomyxa 427
Pomerleau, René, and D. E. Etheridge. A bluestain in balsam fir 155
Porter, C. L. See Gordee and Porter 171
Ramachandra-Reddy, T. K. A new species of Didymosphaeria from the rhizosphere 471
Rangaswami, G., and S. Chandrasekaran. Cercospora species on cucurbitaceous hosts in south India. I. Identification of species 371
Savile, D. B. O. Some fungal parasites of Liliaceae 31
Schwarz, Jan. See Okudaira and Schwarz 53
Sedlmayr, M., E. S. Beneke, and J. A. Stevens. Physiological studies on Calvatia species. I. Vitamin requirements 98; II. Carbon utilization 558
Slifkin, Miriam K. Parasitism of Olpidiopsis incrassata on members of the Saprolegniaceae. I. Host range and effects of light, temperature, and stage of host on infectivity 183
Snell, Walter H., and Esther A. Dick. Notes on boletes. XIV 228
Stambaugh, W. J. See Cobb et al. 91
Stevens, J. A. See Sedlmayr et al. 98; 558
Stevenson, John A., and Chester R. Benjamin. Scleroderma poisoning 438
Stotzky, G. See Goos et al. 262.
Tiffany, Lois H., and Judith H. Mathre. A new species of Elsinoë on Panicum virgatum 600
Tuveson, R. W., and D. O. Coy. Heterocaryosis and somatic recombination in Cephalosporium mycophilum 244
Vinson, J. William. See Jellison and Vinson 524
Vozzo, J. A., and E. Hacskaylo. Mycorrhizal fungi on Pinus virginiana 538
Warren, George H. See Yurchenco and Warren 566
Wells, Kenneth. Studies of some Tremellaceae. IV. Exidiopsis 317
Whiteside, W. C. Morphological studies in the Chaetomiaceae. I 512
Whittingham, W. F. See Cowley and Whittingham 539
Yurchenco, John A., and George H. Warren. A laboratory procedure for the cultivation and fructification of species of Hericium 566

INDEX TO BIOGRAPHIES, REVIEWS, AND NOTICES

Alexander, Martin. Introduction to Soil Microbiology; review 213
Booth, C. Studies of Pyrenomycetes: VI. Thielavia, with notes on some allied genera; review 631
Campbell, W. A. Julian Howell Miller (1890–1961); biography 111
Duran, Ruben, and George W. Fischer. The genus Tilletia; review 213
Ellis, M. B. Dematiaceous Hyphomycetes. III; review 629
Fleming, Mary. See Rogerson and Fleming 552
Hale, Mason E., Jr. Lichen Handbook. A Guide to the Lichens of Eastern North America; review 313
Harrison, Kenneth A. The stipitate Hydnums of Nova Scotia; review 626
Hennig, Bruno. Michael/Hennig Handbuch fur Pilzfreunde; Zweiter Band, Nichtblatterpilze; review 316
Ingold, C. T. The Biology of the Fungi; review 211
Johnson, T. W., Jr., and F. K. Sparrow, Jr. Fungi in oceans and estuaries; review 629

Kreisel, Hanns. Die Phytopathogenen Grosspilze Deutschlands; review 313
Locquin, Marcel, and Bengt Cortin. Champignons Comestibles et Veneneux; review 314
MacLeod, Anna M., and L. S. Cobley. Contemporary botanical thought; review 628
Nattrass, R. M. Host lists of Kenya fungi and bacteria; review 631
Phytochemistry, an international journal of plant biochemistry; review 627
Pilát, A., and O. Ušak. A handbook of mushrooms; review 314
Radiation Botany, a new botanical journal; review 211
Rogerson, Clark T., and Mary Fleming. Publications of William A. Murrill; biography 552
Sutton, B. C. Coelomycetes I; review 629
Weber, George F. William Alphonso Murrill; biography 543

INDEX TO TAXA

New taxa and the pages where they are published are in **bold-face type.** An attempt has been made to correct mistakes in the spelling of scientific names where mistakes occur in the text.

Absidia 406–411; butleri 414, 467; cylindrospora 407, 409, 411; var. **rhizomorpha 409–411**; glauca 541; **pseudocylindrospora 406–409**
Achyla 185, 189–192; americana 186, 188; apiculata 184, 186, 188; bisexualis 184, 186, 188; colorata 184, 186, 188; conspicua 186; diffusa 186; dubia 186, flagellata 185, 186, 188; inflata 186; klebsiana 186; megasperma 186; oblongata 186; prolifera 186; proliferoides 186; racemosa 183, 186; treleaseana 184, 186
Aecidium hyptidis *22*; smilacis 386
Agaricus alneus 580; var. subpetiolaris 580; bisporus 304–306; campestris 305; crispatus 587; multifidus 580; radiatus 581
Alternaria tenuissima 541
Amanita 6; abrupta 539; caesaria 538; flavorubescens 538; frostiana 538; mappa 539; muscaria 6, 538; pantherina 6, 537; parcivolvata 539; phalloides 6, 305, 537–539; rubescens 538; solitaria 538; verna 539
Amanitopsis strangulata 539
Amaurochaete *25–30*; comata *29*; ferruginea *29*; fuliginosa *29*; trechispora *29*; tubulina *29*
Amauroderma **201**
Amphisphaeria 159, 160; aethiops 159; applanata 160; olearum 159; salebrosa 159; thujina 155, 159, 160, 164; umbrina 160
Aphanomyces 185; laevis 186, 188, 192; scaber 186, 192; stellatus 186
Aporpium caryae 490
Apus 579
Arachniotus *221–225*; indicus *221–226*; var. major *221*, *223*, *226*; ruber *226*; trisporus *223*
Arcyria cinerea 139, 142; incarnata 139, 142; insignis 139, 142; nutans 139, 142
Argomyces parilis *22*
Argotelium hyptidis *20*
Armillaria fusipes 84, 85; mellea 84, 85, 87, 89
Arthrobotrys 432, 433; dactyloides 433
Ascobolus 436
Ascotricha 512
Aspergillus *252*; deflectus 434; fumigatus 541; niger 433–436; proliferans 434; ruber 433; terreus 541
Auricularia auricula *2*; auricularis 197; mesenterica 446

Badhamia decipiens 141, 143; macrocarpa 138, 141–144; panicea 138, 141, 143
Basidiobolus 301; meristosporus 281; ranarum 301
Blakeslea trispora 467
Boletellus mirabilis 233, 234; projectellus *233*, *234*
Boletinus flavoluteus 235; glandulosus 235; punctatipes 235; squarrosoides 539
Boletus 124; affinis 539; alutaceus 228; badius 539; betula 539; bicolor 305,

538; calopus 228; cyanescens 539; dichrous 234; edulis 3, 229, 539; erythropus 233; felleus 539; flavissimus 232, 233; frostii 539; glabellus 228; granulatus var. albidipes 232; indecisus 539; junquilleus 232, 233; luteus 539; miniato-olivaceus 6, 232, 233; pallidus 539; pseudosulphureus 233; punctipes 539; queletii 233; retipes 539; rimosellus 539; satanus 6; scaber 305; separans 229, 539; subtomentosus 539; unicolor 232; variegatus 538, 561
Botryodiplodia 263, 270, 274; batatae 264; carpophila 264; cerebrina 264; creba 264; diplocarpa 264; elasticae 264; gossypii 264; manihoticola 264; manihotis 264; phaseolina 264; saccharina 264; theobromae 262–275; tubericola 264
Botryotinia calthae 237; fuckeliana 31, 237, 241, 242; globosa 237; perlargonii 237, 240; squamosa 237
Botrytis 237, 241, 242, 436; cinerea 242; tulipae 237
Boudierella coronata 311
Bourdotia 317–321; galzinii 319; petiolata 321, 365
Bovista 124; gigantea 123; nigrescens 124; pila 124; plumbea 123; radicata 124
Bullaria parilis 22
Byssochlamys 223, 224; fulva 223; nivea 223

Calcarisporium parasiticum 191
Calomyxa metallica 139, 142
Calvatia 4, 98–107, 438, 558–564; bovista 123; caelata 558; cyathiformis 124; fragilis 98, 106, 558, 561–564; gigantea 98, 106, 123–136, 558, 561, 564; maxima 123; primitiva 123; saccata 124, 558
Cenococcum graniforme 539
Cephalosporium 66–78; acremonium 65; mycophilum 244–252; salmosynnematum 65
Ceratiomyxa fructiculosa 138, 142
Ceratocystis fagacearum 91–97
Cercospora 371–377; annamalaiensis 371; citrullina 371, 373; var. **trichosanthei-anguinae** 371–373; cocciniae 376; **chidambarensis 375;** echinocystis 376; elaterii 376; lagenariae 374, 375; liliicola 49; **madrasensis** 373–375; momordicae 371
Cercosporella hungarica 49; inconspicua 49, 50; lilii 49, 50; liliicola 49; terminalis 50; veratri 50
Chaetocladium 442
Chaetodiplodia 263; arachidis 264; coffeae 264; grisea 264; sobraliae 264; vanillae 264
Chaetomidium 512
Chaetomium 512–522; bostrychodes 519; brasiliense 513, 517–522; globosum 513–522; kunzeanum 513; spirale 519; velutinum 513
Choanephora 464–470; cucurbitarum 464, 465; **heterospora** 466, **467,** 468; infundibulifera 464; manshurica 464
Chrysomyxa 427–431; arctostaphyli 427–430; ledicola 427; pirolata 427, 430; weirii 430
Ciborinia 241; erythronii 238–242
Circinella 414–417; angarensis 412, 415–418; muscae 414–418; umbellata 418
Cladonia rangiferina 139
Clastoderma debaryanum 141, 143
Clavariopsis 11–16; aquatica 11; brachycladia 11; **bulbosa** 11–16
Claviceps 5; purpurea 5
Clitocybe illudens 6, 84, 85
Collybia velutipes 561
Coltricia 201
Coltriciella 201
Comatricha aequalis 140, 142; irregularis 140, 142; laxa 141, 143; lurida 140, 143; nigra 140, 143; pulchella 141, 143; tenerrima 140, 143; typhoides 140, 143
Conidiobolus 278–303; adiaeretus 283; brefeldianus 278, 281, 283, 285, 299; chlamydosporus 283; firmipilleus 283; **gonimodes** 283, **292**–303, megalotocus 283; **polyspermus 279**–292, 295, 299, 302; villosus 309
Conocybe 7
Coprinus 104
Coriolus sprucei 207
Corticium sec. Athele 443–450; abietis 349; auricularae 443–446; aurora 443; calceum 348; confusum 443, 448, 449; filicinum 443; galactinum 165; gemmiferum 443–446; glaucinum 443–446; helianthi 443–446, 449, 450; incrustans 318; juncicolum 443; lembosporum 443, 445, 448, 449; leveillianum 362; lividum 345, 368; lloydii 443; macrosporum 351; olivaceum 447; **pausiacum** 445, **447,** 448; spurium 443–448; f. olivacea 443, 447; thymicolum 443; uvidum 345, 346, 368
Coryne 194, 198
Craterium minutum 141, 143
Ctenomyces 224
Cumminsiella 383, 396
Cunninghamella manshurica 464
Cycloporus 201
Cylindrosporium inconspicuum 49; smilacinae 48; veratrinum 50

Dacrymyces deliquescens var. minor 197, 200
Dactylella microaquatica 15
Daedalea 201, 203, 209, 477, 504, 505; berkeleyi 504; confragosa 505; farinacea 504; juniperina 505; pruinosa 206; quercina 206, 207, 505; var. stalactiformis 207; sprucei 201–209; unicolor 505
Daldinia concentrica 2
Dasyspora distorta 23
Delacroxia coronata 281, 283, 301
Densocarpa 218, 219; shanori 219
Dicaeoma fidela 22; hyptidis 21; hyptidis-mutabilis 18; insititium 18; medellinense 21
Dictydiaethalium 25
Dictydium cancellatum 139, 142
Dictyostelium discoideum 183
Dictyuchus 185, 186, 188, 192
Diderma radiatum 142, 143; trevelyani 142, 143
Didymium anellus 143; dubium 143; melanospermum 143, 144; minus 143; vaccinum 142, 143
Didymosphaeria 471–473; astragalina 472; epidermidis 471; galiorum 471; genista 471; peltigera 471; rubi 471; **sadasivanii 471–473**; xylostei 471
Diplodia 159, 263, 265; arachidis 264; cacaoicola 264; cinnamoni 264; cocoarpa 264; cocophila 264; coffeae 264; coffaeiphila 264; coffeicola 264; creba 264; gossypii 263; gossypina 263–265; hesperidica 265; mangostanae 265; manihoti 265; musae 265; natalensis 263–267; paradisiana 265; phaseolina 265; radula 265; rapax 265; solanicola 265; theobromae 264, 265; tubericola 265; zebrina 265
Diplodiella 263
Dothidea graminis 600

Echinodontium tinctorium 501
Echinostelium minutum 140, 142
Eichleriella 318–321, 325, 326; alliciens 322, 323, 354; chinensis 356; deglubens 365; gelatinosa 322, 360; incarnata 318, 322, 354–356, 365; leucophaea 323, 352; leveilliana 322, 356, 362; macrospora 322, 323, 351; mexicana 354, 355; pulvinata 363; schrenkii 353, 354; spinulosa 321, 364, 365
Elaphomyces granulatus 2
Elfvingia 202; brownii 475, 505
Elsinoë 600–604; boucheae 437, 438; **panici 601–603**
Emericellopsis 64–83; **glabra 72–75–82**; humicola 65–76, 80; **microspora 67–76, 80–82, 541**; minima 64–76, 82; mirabilis 65–82; salmosynnemata 64–66, 70, 74, 76, 79–82; terricola 64, 65, 76, 80, 82; var. glabra 64–66, 70, 75, 82; var. terricola 65, 66, 69, 70, 75
Emmonsia crescens 524–535
Empusa 311; fresenii 301; geometralis 301; lageniformis 301; occidentalis 301
Endogone 254–260; fasciculata 254
Endophyllum 397
Entoloma lividum 6
Entomophthora 307, 311; coronata 307–312; sphaerosperma 302
Eriosporangium fidelis 22; hyptidis 20; hyptidis-mutabilis 18; medellinense 21
Exidia 317, 322, 363; subg. Exidiopsis 326; effusa 346; glandulosa 322; nucleata 320, 321, 363, 367; rolleyi 363
Exidiopsis 317–370; **alliciens** 328, 345, 351, **354–357**, 362; **calcea** 328, 345, **348–351**; calospora 322, 324, 326, 328, 331; **candida** 327, **334**, 339, 358; cerina 317; effusa 317, 341, 346; fugacissima 322, 323, 327, 331, 332, 337, 339; fuliginea 322–324, 327, 335–337; glaira 322, 324, 327, 331, 332, 339; grisea 322, 324, 327, 341, 343–346, 354, 358, 365, 368; **laccata** 327, 339, **340**, 345; **leucophaea** 327, 350, **352**, 354; **macrospora** 328, 345, 348–**351**, 352; manihoticola 346, 347; moelleri 357; molybdea 322, 324, 327, 331, 332, 339, 345; mucedinea 324, 328, 346; peritricha 342; plumbescens 342; prolifera 322, 324, 326, 329, 331, 365; sordida 334, 335, 345, 357, 358; sublilacina 367; **sublivida** 328, 345, **347**, 348; quercina 341, 345, 346

Favolus 477, 506; alveolaris 506; canadensis 506
Flabellaria 579
Fomes 477, 499–502; abietis 499; abramsianus 500; annosus 502; arctostaphyli 500; badius 501; cajanderi 501; carnea 501; conchatus 500; connatus 501; demidoffii 501; earlei 501; ellisianus 502; everhartii 500; fomentarius 3, 4, 499; fraxinophilus 502; fulvus 500; hartigii 500; igniarius 490, 500; isabellina 499; juniperinus 501; laevigata 500; laricis 502; marginatus 502; marmoratus 499; medulla-panis 502; nigrolimitatus 490, 499; nobilissimus 501; occidentalis 499; officinalis 2–4, 502; ohiensis 502; piceinus 499; pini 499; pinicola 502; pomaceus 500; ponderosus 502; populinus 501; praerimosus 500; prunicola 500; punctata 500; putearius 499; radiciperda 502; repandus 490, 500; ribis 500; rimosus 501; robineae 501; robustus 490, 500;

roseus 501; sclerodermeus 499; scutellatus 502; setosus 499; subrosea 501; tenuis 499; tinctorius 501; ulmarius 147; ungulatus 502; unitus 496, 502; viticola 490, 499; vorax 499; weirianus 500
Fomitiporella 202
Fuligo septica 138, 141, 143
Fusarium 244, 245, 251; oxysporum 541; f. gladioli 251; f. pisi 251; roseum 7; solani f. cucurbitae 251; sporotrichioides 7
Fuscoporella 202

Galera tenera 305
Gambleola 396, 397; cornuta 397
Ganoderma 202, 475, 477, 505, 506; **annularis 505**; applanatum 357, 446, 505; **brownii 505**; lobatum 505; lucidum 506; megaloma 505; oregonense 506; sequoiae 506; tornata 505
Genabea 215, 216, 218
Genea 216, 218; bombycina 218
Geopora 217
Gilbertella persicaria 467
Globifomes 202
Gloeocystidium sec. Athele 443, 450; cretatum 445, 450
Gloeophyllum 201, 203, 209
Gloeosporium musarum 270, 273
Gongronella butleri 409, 412–415; **lacrispora** 409, **411–415**
Gymnoascus 224, 226; flavus 223
Gymnoconia hyptidis 20, 21
Gymnosporangium 436
Gymnotelium 386, 390
Gyromitra esculenta 537

Haplosporangium 527; decipiens 442
Heliscus 11
Helvella esculenta 7
Hemitrichia clavata 140, 142; serpula 140, 142; stipitata 140, 142; vesparium 140, 142
Hericium 566–574; abietis 568; caputursi 567–573; coralloides 568, 569, 573; erinaceus 566–573; henningsii 568; septentrionale 568–573
Heterochaeta 317–323, 348, 352, 361, 367; delicata 321; dubia 318; lividofusca 321; macrochaeta 367; sublivida 323, 347, 348; tremellispora 361
Heterochaetella 318, 319; dubia 321
Hexagona 201, 203; aequalis 203–208; erubescens 203–207; glabra 206
Hirneolina 318, 319, 322; crocata 354, 355; gelatinosa 360; hirneoloides 361; incarnata 354; leucophaea 353; schrenkii 353; ubatubensis 354, 355
Histoplasma capsulatum 53, 59–62; duboisii 53–63
Hydnocystis 217; **singeri 216**
Hydnoplicata 217, 218; whitei 216
Hydnotrya 217, 218
Hygrophorus conicus 6
Hymenochaete dendroidea 356
Hyponeuris 579; alneus 581
Hypoxylon 112

Ichthyosporidium 432
Inocybe infelix 6; infida 6
Inodermus 202
Inonotus 202
Institale bombacina 357
Irpex 201; rickii 204–208; sprucei 204, 208
Isoachyla 185, 190; angiospora 186; monolifera 186, 192; unispora 186, 192

Kirschsteiniella **thujina** 156, 159, **160–169**

Lactarius colorascens 305; piperatus 3, 305; torminosus 3, 6
Lactea brunneola var. brasiliensis 587
Lambertella copticola 238; hicoriae 238, 240
Lamproderma arcyrionema 141, 143; sauteri 138, 141, 143
Lasiodiplodia 263, 264; nigra 265; theobromae 264, 265; triflorae 265; tubericola 263, 265
Leccinum 234; rubropunctum 234
Lemonniera 12
Lentinus resupinus 592
Lenzites 201, 477–506; abietinella 506; betulina 506; distancifolia 204–207; hirsutum 506; saepiaria 506; striata 506; trabea 506
Leocarpus fragilis 142, 143
Lepidoderma carestianum 138, 143, 144
Lepiota lutea 305; morgani 6; rhacodes 538
Licea fimicola 138, 142; kleistobolus 138, 142
Lithodermyces 579
Lophotrichus 512
Lulworthia salina 15
Lycogala epidendrum 138, 139, 142
Lycoperdon 4, 123, 124, 127, 131, 133, 438; atropurpureum 124; bovista 123; constellatum 123; echinatum 124; gemmatum 123, 124, 539; giganteum 123; nigrescens 124; pratense 124; pyriforme 124; umbrinum 124; wrightii 124

Macrophoma vestita 265
Melampsorella caryophyllacearum 427
Melanoporella 202
Melanoporia 202
Merisma candidum 318

Merulius tremellosus 197
Micropuccinia distorta 23
Microsporum quinckeanum 529
Mollisia 194, 197
Mucilago spongiosa 142, 143
Mucor 417, 418; angarensis 415; hiemalis 540, 541; recurvus 184; sexualis 422
Mycena galopus 84, 85; polygramma 84, 85
Myriangium bambusae 600
Myriosclerotinia sulcata 238
Myrmecocystis 215–218; compacta 216; **spinospora 215**, 216
Myxotrichum 224

Nematodiplodia laelio-cattleyae 265
Neobulgaria pura 194, 197, 198
Neurospora 251; crassa 91, 96, tetrasperma 180
Nyssopsora 396

Olpidiopsis 183, 184; incrassata 183–192
Omphalia flavida 84, 85
Oospora sulphurea 541
Ovulinia azaleae 242

Paecilomyces marquandii 541
Panaeolus 7
Panus stipticus 84–89
Paxillus rhodoxanthus 539
Penicillium 124, 222, 252, 451–463; albicans 452; canadense 451, 452; chrysogenum 66; cyclopium 251; daleae 451–454; frequentans 460; granulatum 541; herquei 541; implicatum 541; janthinellum 454, 541; lilacinum 541; lividum 460; luteum 221, 226; nigricans 541; notatum 8; **odoratum 459–462**; **pinetorum** 456, **457**, 458; purpurogenum 541; radulatum 451, 455; restrictum 541; roqueforti 115–121; roseo-purpureum 541; simplicissimum 541; spinulosum 541; thomii 458; trzebinskianum 460; variabile 541; vermiculatum 224
Perichaena chrysosperma 139, 142; corticalis 139, 142, 144; depressa 139, 142, 144; vermicularis 139, 142, 144
Perisporium funiculatum 522
Peritrichospora integra 15
Petchiomyces 218
Peyronellula mirabilis 64
Peziza proteana 278
Phaeodaedalea 201–**203**–209; **sprucei** 202–**203**–209
Phaeoschizophyllum 580, **594**; **leprieuri** 580, 594, **595**
Phallus impudicus 2
Phellinus 202
Phialophora 541
Phleospora vagnerae 48
Pholiota autumnalis 6
Phyllachora 600
Phyllosticta melanoplaca 49
Phymatomyces 217; yezo-montanus 217
Phymatotrichum omnivorum 181
Physalospora 264, 265; rhodina 264, 265, 273
Physarum cinereum 141, 143; compressum 141, 143; galbeum 141, 143; mutabile 141, 143; notabile 141, 143; nutans 141, 143; pusillum 141, 143; tenerum 141, 143
Polyporellus varius 446
Polyporus 104, 477–489; abietinus 488; adustus 484; albellus 486; albidus 486; alboluteus 484; amarus 482; amorphus 487; anceps 488; annularis 475, 505; arcularius 482; aurantiacus 484; balloui 480; balsameus 486; benzoinus 486; berkeleyi 479; betulinus 482; biennis 480; biformis 485; borealis 485; bresadolae 484, 491; brumalis 482; caesius 487; canadensis 483; carbonarius 486; cinnabarinus 487; cinnamomeus 478; circinatus 477; confluens 480; corruscans 478; crispellus 486; crispus 485; cristatus 480; cryptopus 481; cuneatus 483, 491; cuticularis 479; cutifractus 486; decurrens 481; delectans 483; dichrous 485; dispansus 480; distortus 480; dryadeus 478; dryophilus 478; dualis 477; elegans 481; ellisii 480; farlowii 479; fibrillosus 484; fissus 482; flavovirens 480; flettii 480; floriformis 482; fomentarius 3; fragilis 485; frondosus 481; fuliginosum 486; fumosus 485; galactinus 483; giganteus 481; gilvus 478; glomeratus 479; griseus 479; guttulatus 486; hirsutulus 488; hirsutus 479, 489; hirtus 481; hispidellus 481; hispidus 479; illudens 480; immitis 486; lapponicus 485; leucospongia 485; macounii 488; mcmurphyi 481; melanopus 481; minusculoides 484; mollis 484; montagnei 478; montanus 479; munzii 479; nidulans 482; nigromarginatus 489; obtusus 483; officinalis 2–5; oregonensis 480; osseus 482; ovinus 480; pacificus 485; pargamenus 488; perdelicatus 487; perennis 478; pes-caprae 480; picipes 481; pini-ponderosae 484; planellus 487; planus 487; polyporus 482; pseudotsugae 485; pubescens 489; radiatus 478; resinosus 486; rheades 478; rubricosa 488; rutilans 482; schini 479; schweinitzii 477; sector 488; semipileatus 487; semisupinus 483; sensibilis 485; sistotremoides 477; skamanius 480; specio-

sus 483; spragueі 483; spumeus 483; squamosus 481; stipticus 488; subcartilagineus 485; subchartaceus 488; subradicatus 481; subsquamosus 479; substipitatus 486; sulphureus 483; supinus 487; sylvestris 480; tephroleucus 486; texanus 479; tomentosus 477; trabeus 486; tuberaster 481; tuckahoe 481; tulipiferae 484, 492; umbellatus 482; undosus 485; unicolor 483; ursinus 485; varius 481; velutinus 489; versatilis 488; versicolor 488; volvatus 487; vulpinus 478; washingtonensis 483; zelleri 482; zonatus 489
Poria 475, 477, 489–499; albipellucida 493; albobrunnea 497; albolutescens 493; alpina 475, 498; alutacea 498; ambigua 492; andersoni 489; aneirina 494; argillacea 490; asiatica 494; attenuata 496; aurea 493; avellanea 495; bombycina 493; byssina 484; callosa 497; candidissima 493; canescens 490; carbonica 497; carnegiea 494; carnicolor 495; chromatica 497; cinerascens 497, 499; cocos 492; colorea 496; coniferarum 493; corticola 491; crassa 496; crustulina 497; cylindrospora 489; decolorans 492; dichroa 497; eupora 496; fatiscens 491; ferox 497; ferrea 489; ferrugineofusca 489; ferruginosa 490; fimbriatella 495; fulvella 493; griseoalba 491; incarnata 495; incrassata 493; johnstonii 495; laevigata 490; latitans 494; leei 489; lenis 498; lenta 495; luteoalba 498; luteofibrata 496; mappa 495; marginella 489; microspora 495; mollusca 493; monticola 495, 499; myceliosa 493; nigrescens 492; notata 494; obliqua 489; overholtsii 496; pannocincta 494; parksii 492; placenta 495; purpurea 491; radiculosa 496; radula 496; rancida 497; reticulata 491; rhodella 491; rimosa 495; rixosa 496; rubens 495; rufa 492; salmonicolor 495; sanguinolenta 492; var. expallescens 492; semitincta 491; sequoiae 499; sericeomollis 494; šimani 494; similis 491; sinuascens 498; sinuosa 498; sitchensis 498; spissa 492; stellae 498; stenospora 497; subacida 496; subavellanea 497; subfuscoflavida 497; subiculosa 490; subincarnata 498; subtilis 493; subvermispora 494; tacamahacae 494; tarda 491; taxicola 492; tenuis 496; var. pulchella 496; terrestris 492; undata 492; vaillantii 496; vaporaria 498; versipora 494; vicina 491; viridans 491; vulgaris 494; weirii 489; xantha 497, 498; xanthospora 489; zameriensis 494; zonata 497
Porotheleum fimbriatum 490
Protoachyla paradoxa 185–188, 192
Protodontia 318, 321; piceicola 321; uda 318, 321
Protohydnum 318; cartilagineum 321
Protomerulius 357
Psathyrella 7
Pseudoarachniotus 224
Pseudotremellodendron 365
Psilocybe 7; baeocystis 538
Puccinia 17–23; subg. Bullaria 386, 390; sec. Eupuccinia 386; clan **Brevipedicellae** 383, **387,** 389; sept **Pygmaea** 382, **387,** 388; sept **Rubigo-vera 388,** 389; clan **Longipedicellae 383**–387; sept **Berberidis** 382–**383,** 384, 396; 397; sept **Culmicola** 384–**386,** 387, 393, 397; sept **Phragmitis** 382, **384,** 385, 386; kin Berberidae 387, 396; aegilops 389; alii 42, 43; amphiospora 18; anthoxanthi 380, 387; aristidae 39; arnaudi 389; arrhenatheri 388; arundinariae 382, 386; asparagi 39; atropuncta 33; avenae-pubescentis 380, 387; baryi 388; berberidis 382, 384; berberidis-trifoliae 384; bessei 38, 39; blasdalei 41–44; brachypodii 387, 388; brunellarum-moliniae 386; calochorti 36; caricis-montanae 380; cerinthes-agropyrina 389; culmicola 380, 387; dactylidis 381, 387; dispersa 389; distorta 17, 19, 23; ellisiana 39; fidelis 17, 19, 22, 23; gibertii 21, 22; glumarum 382, 388; graminis 378–405; subsp. minor 387; var. tritici 384, 398; granulispora 41, 42; grumosa 33; heimerliana 387; hordei 382; hyptidis 17–21; hyptidis-mutabilis 17–22; imperatae 387; insititia 17–19; inulae-phragmiticola 384, 393; isiaceae 385; koeleriae, 382, 388; **kukkonensis 38;** medellinensis 17, 20–22; mesomajalis 37; meyeri-alberti 382, 384; milii 388; mixta 42; moliniae 386; montanensis 382, 388; mutabilis 42–44; nemoralis 386; obtusata 384, 393; ornata 384, 393; pagana 38, 39; parilis 17, 20, 22; perfuncta 22; phlei-pratensis 380, 387; phragmitis 382–386, 393; poae-sudeticae 382, 388; porri 42, 43; pygmaea 382, 388; recondita 388; rubigo-vera 388, 389; scillarum 45, 47; sesleriae-coeruleae 380; sporoboli 34; symphytibromorum 389; trabutii 384–386, 393; traillii 384, 393; trebouxii 387; veratri 3, 50
Pyropolyporus 203
Pythium debaryanum 291; ultimum 291, 302

Radulum deglubens 364; kmetii 364; spinulosum 364
Ramularia smilacinae 50; subsanguinea 50
Retinocyclus abietis 167
Rhipidium 579
Rhizoctonia 436; solani 183, 184
Rhizopogon roseolus 538
Rhizopus arrhizus 422; **homothallicus 419–422**; sexualis 420–425; var. **americanus** 420, **424**, 425
Rhodotorula mucilaginosa var. sanguinea 126, 127, 135
Rhopalomyces elegans 442
Russula 605–625; alcalinicola 605, 606; astringens 605, 606; badia 616; betulina 606, 607; bicolor 607, 608; blanda 607, 608; californiensis 608, 609; corinthiirubra 609, 610; cremoricolor 609, 610; crenulata 609, 610; davisii 609, 612; disparilis 611, 612; echinospora 611; emetica 6, 539; ssp. emeticella 609; fucosa 611, 612; fulvescens 611, 613; fusca 611; gracilis 611, 613; gracillima 614; helodes 622; hibbardae 613, 614; humidicola 614, 615; integra 607; lactea 607; lepida 607; luteotacta 616; marginata 614, 615; mariae 624; maxima 614, 615; mexicana 616, 617; mordax 616, 617; murina 616, 617; murrillii 616, 618; olivacea 611; operta 618, 619; ornaticeps 618, 619; parvula 619, 620; placita 619, 620; praeumbonata 620, 622; punctata 619; pusilla 619; queletii 622; redolens 621, 622; robinsoniae 621, 622; rubriochracea 621, 622; stricta 623, 624; subtilis 623, 624; sulcatipes 623, 624; variegata 614; velenovskyi 607; xerampelina 624; zelleri 623, 624
Rutstroemia 238; paludosa 238, 240

Saccharomyces cereviseae 5
Saprolegnia 183–192, 436; delica 186; diclina 186; ferax 183–189; kauffmaniana 184, 186; mixta 186; parasitica 185–192
Saturnomyces humicola 64
Scaphophorum 579; agaricioides 581
Schenella 25–30; **microspora** 27, **29**, 30; simplex 25–28
Schizonia 579
Schizophyllum 575–599; album 581; alneum 581; **brasiliense** 580, **593**, 596, 597; brevilamellatum 577, 578, 585, 586; commune 195, 197, 575–577, 580, 585–592, 596–598; f. dictiflorum 587; f. flabellare 586; f. fuliginea 587; f. lobatum 581, 586; f. maxima 586; f. multifidum 586; var. flabellare 586; var. incisum 581; var. laceratum 587; var. maxima 581; var. minor 587; var. multifidum 586; var. orbicularis 587; var. palmatum 581, 587; var. vetustum 587; egelingianum 581, 586; exiguum 581; fasciatum 577, 580, 589, 590, 596, 597; var. mexicanum 590; flabellare 581; var. pallidum 587; leprieuri 577, 595–598; lobatum 581, 596; mexicanum 589, 590, 597; var. incisum 589, 590; miia 580; multifidum 581, 587; var. digitatum 591, 592; murrayi 581; **palmatum** 580, **592**, 596, 597; pavonium 581, 590; pusillum 587; radiatum 577, 581, 585, 586, 589, 598; ramosum 587; umbrinum 577, 580, 591, 592, 596, 597; variabile 596; vulgare 581, 588
Schizophyllus 579; commune 581
Scleroderma 124, 438, 439; aurantium 124, 438, 439; cepa 439; vulgare 124, 438
Sclerotinia 241, 242; asari 238; sclerotiorum 238, 240; trifoliorum 238
Seaverinia geranii 238
Sebacina 318–322, 325, 357; adusta 335–337; alutacea 359; ambigua 359; atra 332–334; bresadolae 359; burti 342; caesia 359; calcea 322, 324, 349, 351; var. corticoides 351; calospora 328; candida 322–324, 334, 335; crozalsii 360; dendroidea 356; effusa 341; epigaea 319, 320, 359, 360; fugacissima 337; fuliginea 335; galzinii 318; glauca 341, 343, 346; gloeofilum 361; grisea 342–346; helvelloides 319, 320, 359, 366; hirneoloides 318, 322, 361; incrustans 319, 320, 359, 366; laccata 322, 324, 340, 341; laciniata subsp. caesia 359; letendreana 348; macrospora 351; mesomorpha 340, 341; microbasidia 326, 362, 363; molybdea 332–334; monticola 351, 352; mucedinea 322, 346; opalea 331; peritricha 342, 343, 346; plumbea 342, 343, 346; plumbescens 342, 343, 346; podlachica 320, 321, 339, 358–367; prolifera 329; quercina 341; reticulata 357; rufochracea 357; sordida 357; sphaerospora 363, 364; spongiosa 366; strigosa 366; subhyalina 367; sublilacina 321, 339, 358, 361, 363, 367; tenuis 358; tuberculosa 358; umbrina 342, 343, 365; uvida 342, 343, 346, 368; subsp. peritricha 342, 346; variseptata 335, 336
Septoria streptopodis 49
Skepperia 575
Sphaceloma 603
Sphaeria thujina 159–161
Stachybotrys alternans 7
Stemonitis 29; axifera 140, 142; flavogenita 140, 142; fusca 140, 142; pal-

lida 140, 142; splendens var. flaccida 29; trechispora 29; virginiensis 140, 142
Stephensia 217–220; arenivaga 220; bombycina 218–220; crocea 220; peyronelii 220; **shanori 219, 220**; sumatrana 218–220
Stereum 145, 147; alliciens 354; calceum 147; leveillianum 362; sanguinolentum 163–169; sulcatum 145, 146, 149–153; taxodii 145–153
Streptomyces 292
Streptotinia 238; arisaemae 238, 240
Strobilomyces strobilaceous 539
Stropharia 7
Stypella 318, 319; minor 320, 321, 363, 364, 367; papillata 321
Suillus albidipes 230–232; **flavoluteus 235; glandulosus 235;** granulatus 232; subsp. **albidipes 232;** subsp. snellii 230–232; placidus 230, 231; **punctatipes 235;** sibiricus 229, 230
Syncephalastrum 194, 197, 200
Syncephalis 440–442; nana 441; tenuis 441

Talaromyces 221, 222, 225, 226; luteus 225, 226; vermiculatus 221, 223, 226
Thelephora acerina var. abietis 348; caesia 359; calcea 348; c. albidofuscescens 348; effusa 326, 341; glauca 341; grisea 341, 345; hirneoloides 361; letendreana 348; mucedinea 346; reticulata 357; viscosa β uvida 345
Thielavia 521, 522; sepedonium 520, 521; terricola 521
Thielaviopsis paradoxa 273; sulphurellum 541
Thraustotheca clavata 185–188, 192
Thyridaria tarda 265
Torulopsis sanguinea 124, 127
Trametes 475, 477, 502–504; alaskana 504; americana 503; callosa 504; campestris 504; carbonaria 490, 502; colliculosa 503; heteromorpha 504; hispida 503; malicola 503; mollis 503; odora 503; sepium 504; sequoiae 503; serialis 497, 504; sprucei 207; stuppea 503; suaveolens 3, 503; trogii 503; variiformis 504
Tremella 322; concrescens 320; epigaea 359; glaira 331; sordida 325, 334, 335
Tremellodendron 318–321, 359
Tremellodendropsis 321
Trichia affinis 140, 142; botrytis 139, 142; persimilis 139, 142; pusilla 140, 142; varia 140, 142
Tricholoma 124
Trichophyton quinckeanum 529
Triplosporium 301
Tubifera ferruginosa 25
Tuburcinia clintoniae 31

Uredo amphiospora 18; concentrica 45; hyacinthi 46; hyptidis 20; hyptidis-atrorubentis 21; limbata var. muscari 46; muscari 45; scillarum 45
Urocystis cepulae 32; colchici 32; erythronii 32
Uromyces 383, 386; aemulus 44; algeriensis 48; caladii 195, 197; circinalis 48; concentricus 45; dactylidis 380; heterodermus 35; holwayi 34, 35; hyacinthi 46; inaequialtus 39; limbatus 46; limonii 39; macowani 48; miurae 36; muscari 44–48; f. sp. **hyacinthi 46;** f. sp. muscari 46; f. sp. **muscari-racemosi 46;** f. sp. **scillae 46;** nothoscordi 39, 40; polygoni-avicularis 39; primaverilis 39; ssp. **nothoscordi 40;** ssp. **primaverilis 40;** scillarum 45, 48; f. sp. hyacinthi 46; f. sp. muscaricomosi 46; f. sp. muscari-racemosi 46; f. sp. scillae 46; zygadeni 33
Ustilago 5; heufleri 32, 33; maydis 5

Verticillium albo-atrum 171–181

Xanthoconium **purpureum 234**
Xenasma 443–450; filicinum 449
Xerocarpus farinellus 348
Xerocomus **alutaceus 228**
Xerotus 201

Zygorhynchus 422; macrocarpus 412, 418, 419

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